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**THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES' EQUIPMENT AND SUPPLIES ASSOCIATION.**

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## Marketing Light Castings.

Over 10,000 tons of foreign-made castings, valued at about £500,000, for the building industry are arriving in the country every year. The two major items are bath tubs and oil-fired stoves for domestic cooking and heating. It needs but little imagination to visualise the percentage of this £500,000 which would have been paid by way of wages to moulders, fettlers, patternmakers, cupola-men, blast-furnacemen, sand and iron-ore quarrymen and transport workers. Then, of course, the fuel for smelting the ore, melting the iron and carrying out auxiliary operations would keep a fair-sized colliery quite busy for 24 hours. But the more serious aspect is that these imports, when added to normal production would help to ease off some of the essential overhead costs, thus alleviating the cost of the general output, with the possibility that lower costs so brought about would facilitate the entry of British light castings into foreign markets.

It must be borne in mind that most of these imported castings are of the repetition variety, and are partially the result of standardisation or, at least, the ability of the builders' merchants to place large orders for one type of article.

Since the beginning of 1930, one very large corporation of builders' merchants has been busy with the standardisation of the materials they handle, including a certain number of castings. Some of the factors involved are not superficially evident to the founder, and have reference to stocking. Naturally, the carrying of "in-between" sizes locks up money, whilst if castings can be "nested," storage space can be saved. In the foreword to a pamphlet this corporation has produced, their work is described as an offensive against foreign competition, by compelling (*inter alia*) the foundry owner to reform his manufacturing and marketing methods.

Whilst "compulsion" sounds to us an ugly word, and "standardisation" is interpreted by us as another weapon to place in the hands of foreign manufacturers, we realise that the motives actuating the publishers of this pamphlet are honest and praiseworthy. The builders' merchants realise that the demand for the goods they handle varies with the prosperity of the country they serve, and that it is, in the long run, good business to support home industries.

Again, they have realised that, whilst in the past they invariably placed large repetition orders abroad, they parcelled out in small quantities their home requirements. Now they are prepared to accord really large orders to British firms. In this connection, we would issue a word of warning to those who have the placing of really large orders for standardised castings. Primarily, expensive pattern plates have to be made, together with the creation of a fund for the elimination of those automatically made obsolete; moulding machinery may have to be installed, and, finally, provision has to be made for the transport of material to and from the machines. Some of the leaders amongst the builders' merchants imagine that external transport is a major factor in the cost of the production of castings, but we give that particular place to "internal" transport. Thus builders' merchants must be particularly generous to the foundries in the early stages. The use of "country" founders, with low overheads, is but an ephemeral panacea to the meeting of Continental prices. A proper understanding between the organised employers' federations on both sides should result in their mutual benefit, whilst still conferring a boon upon the ultimate consumer—the general public.

## Education for the Engineering Industry.—I.

The report just published by the Board of Education, under the above title, is unusual for several reasons, and of special interest to founders, because it is the first report of its kind we have ever read in which the foundry trade has its full share of consideration. The Committee responsible for it was asked to advise the Board as to the scope and methods of the inquiry it was carrying out into technical education for the engineering industry. Its personnel of thirty included Mr. E. R. Briggs, Mr. A. P. M. Fleming, Sir Henry Fowler, Sir Robert Hadfield and Mr. W. Reavell, all of whom have shown their interest in one way or another in the foundry trade.

Reference to the foundry trade is made in several places in the report, and in one section a special paragraph is given. The main difficulties mentioned are two—the difficulty of recruitment, that is, of obtaining a sufficient number of youths, and, secondly, the difficulty of providing instruction for youths who are, on the average, of lower ability than those in other branches of engineering. It is suggested that with improvement in working conditions a better type of recruit will be obtained, and that this, in turn, will mean better material for the schools.

The report then goes on: "We are encouraged by the great interest taken in the matter by the Institute of British Foundrymen. That body supplied us with a valuable memorandum, and it is obvious that it has given very careful consideration to the educational needs of this branch of the industry. We understand that an Advisory Committee has been appointed to deal with educational matters, and that it will co-operate with the City and Guilds of London Institute in the holding of examinations for young foundrymen. This considered attempt to improve the education of foundry workers throughout the country is one which should be cordially supported by the schools, and we trust that the Institute of British Foundrymen will be successful in their efforts to stimulate the interest of employers and foremen, since such interest is essential to the effectiveness of the scheme. In addition, it may be found possible to introduce a substantial element of foundry work into the Senior and Advanced Courses of the National Certificate, in order to meet the needs of those who may be expected to take responsible managerial positions in this branch of the industry. Our attitude to such an experiment would be wholly favourable."

Such endorsement is indeed a triumph for the scheme.

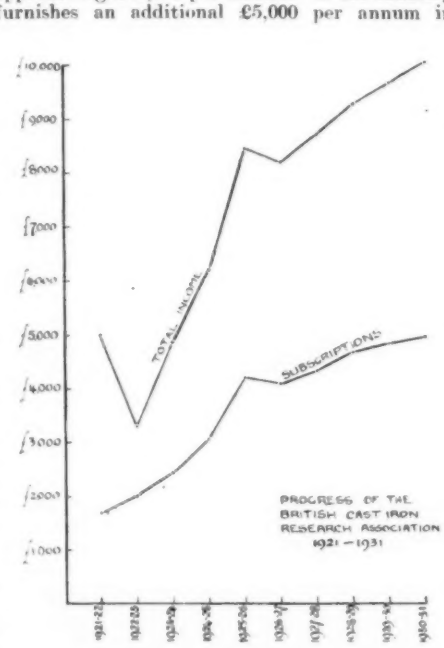
# British Cast Iron Research Association.

## A RECORD OF PROGRESS.

It is a little difficult for us in these times to understand the conditions which existed in industry from the Armistice until 1921. The atmosphere was one of reconstruction. Demand was great and the necessity for adapting industries to the requirements of peace production rendered supplies difficult to obtain. The general air of optimism obscured for the moment the fact that capital destroyed during the war would require to be replaced. It was during this period that activity in the formation of research associations was at its height. The demands of the war period had shown such deficiencies in various departments of British industry that the Government resolved to promote by all the means in its power the conduct of scientific research in industry and its application to production. About a score of these associations were founded on the principle of aiding producers in a given industry to group together for the purpose of conducting and applying research. The encouragement offered took the form of a Government grant equivalent to subscriptions raised in the industry, that is, eightpence if not ninepence for fourpence. It was originally intended that the grant should be paid for a period of five years, after which it was anticipated that the Associations would be strong enough to ask their industries to bear the whole of the cost involved. This view did not make sufficient allowance for the collapsing of the post-war boom referred to, and when, in fact, the British Cast Iron Research Association was ultimately formed in 1921, signs of the collapse were beginning to be evident. For the first two or three years of its existence the Association had to work against the handicap created by these unfavourable conditions, but ultimately the difficulties were overcome, as is shown by the diagram. This shows subscription income from the industry and total income for ten years, 1921-31. (The figures for 1930-31 are subject to audit.) With the exception of a very slight recession during one year, following the coal dispute, each year has shown an increase in subscription income and in total income, the difference being mainly due to the Government grant. During this period the subscription income has very nearly trebled, and this should make it clear that the situation with which the Association is now faced is not in any way due to loss of membership. On the contrary, the membership has shown regular increase each year.

The original Government grant was guaranteed for a period of five years, and when this came to an end the Association appealed on various grounds for it to be continued. The Government thereupon appointed three impartial and independent inspectors of a very high standing to examine the Association's work, and their report (1926) was of such a favourable character that the Government intimated its willingness to continue the £1 for £1 grant for a further three years (1925-26 to 1928-29), with a grant of 10s. in the pound for each £1 of industrial subscriptions received for a period of two years (1929-30 and 1930-31). It was intimated that grant would entirely cease with the expiry of this second five-year period. However, at the end of the three-year period the Council did not consider that the condition of the industry justified any attempt to increase the income which it furnished, and the Government was therefore asked to continue the £1 for £1 grant for the remaining two-year period. Finally this proposal was accepted, subject to the Council in turn agreeing to definite conditions for the receipt of grant for the period following 1930-31, that is, the period beginning July 1 of this year. The Council accepted the conditions. They were briefly as follow: The subscription income, as will be seen from the diagram, was gradually approaching £5,000 per annum, and the Government stated that they would not pay grant after June, 1931, on subscriptions up to this figure. They agreed, however, to pay grant at the usual £1 for £1 rate on subscriptions received *over and above* this sum up to a similar sum of £5,000. The Government thus indicated its willingness to continue the grant on the same scale as hitherto, and this will be carried on for a period of at least ten years, the only condition being that the support from the industry should be increased. The Council of the Association is to be congratulated on ensuring this continued grant when its discontinuance had been threatened.

It will be obvious that on a subscription income approaching £5,000 per annum the Association has been able to spend each year a total income approaching £10,000 per annum. If the industry furnishes an additional £5,000 per annum in




subscriptions beyond the original £5,000 hitherto received, the total income will be, with the grant, £15,000. The Council is satisfied that, if the expanding work of the Association is to be provided for adequately, this additional income is essential. In fact, the urgent necessity for further accommodation has made it necessary for the Council to presume to some extent on the additional income being raised, and it has been possible to obtain favourably situated accommodation at its present headquarters which will materially add to the space already occupied. We propose in subsequent issues to give the leading features of the work of the Association and how it may benefit the industry.

In most of the industries in which research associations have been formed, powerful manufacturers' associations exist, which have taken over complete responsibility for financing the research association by means of a levy on members. The variety of interests represented in the foundry trade makes this impossible, and it has been necessary to increase membership by approaching individual foundries, and hitherto no group memberships of foundries in the various trade associations have been made. The Council, however, is quite prepared to arrange group memberships if so desired by the interests concerned.

## Random Shots.

The foundry and machine shop make possible all generated power, heat and light; all transportation by land, water and air; all communication by telegraph, telephone and radio; all agricultural machinery; all textiles and clothing; all printing and paper. Everything we use at home, at work, at play is the child or grandchild of a machine tool.

* * *

Two committees in the United States are now engaged upon the preparation of foundry displays for the New York and the Chicago Museums of Science and Industry. And the above paragraph is the wording for a large sign which will appear in the foundry and machine-shop section of the New York Museum. A worthy scheme this, that Kensington might emulate. And in support of the "brighter museums" movement, the wording of the sign might be altered somewhat. A few facts conveyed in the style of the following ought to convince people just how important the art of founding is:—

Without the foundry and the machine shop you could not travel by aeroplane, train, tram, car or bicycle; they would not exist. You could not enter this building; it would not exist. You could not go to theatres or cinemas; they would not exist. You could not read by electric light at midnight; it would not exist. You could not buy your morning, midday and evening newspapers; they would not exist. You could not use the telephone to explain how late you will be kept at the office; it would not exist. You could not wear the clothes you do; they would not exist. How are you to know that you would not exist? Everyone we meet at home, at work, at play is, perhaps, the descendant or relative of someone whose life was, or might have been, saved by castings.

* * *

In a fascinating book of memoirs—"Friends and Adventures"—"T." of "Punch" defines "service" as "doing everything a little better than it need be done." And asks, "What ideal of service was there in that firm of safety-razor makers which, I am credibly informed, spent a large sum of money trying to find a formula for a case-hardened steel of such a temper that the blade should not stand up too long?" Beards of Shylock and Rip Van Winkle, none!

* * *

A writer suggests that among the things badly needed, but not yet invented, are steel goloshes for use in crowded trams and omnibuses. These goloshes, he stipulates, should be light, flexible (allowing one to slip them on before entering the vehicle) and capable of affording complete toe-protection. Metallurgists ought to be literally on tip-toe to provide a steel suitable for the purpose.

* * *

IMAGINARY INTIMATE INTERVIEWS.

X.—*The Cab Driver.*

Nowadays, mind you, what with two and a-half millions not able even to struggle for a living, I don't expect to get the tips I did in brighter days. I tries to cheer up my fares, sometimes, bein' joky and polite. An' it's that funny, instead of grumbling and swearing that Tishy's meter is all wrong, they fair overwhelms me with gen'rosity. One old gent' I picked up outside the Mile End synagogue, Saturday evenin', gave me a ten-bob note and would *not* take his change. So I put it in an orphans' charity box at the first coffee stall I stopped at. These times, they try you, but they do make you more sympathetic-like. Here's your thruppence change, sir. Oh, thank you very much, sir! Good-night, sir.

MARKSMAN.

# Castings for High-Temperature Service.

Professor Hanson's address* formed the basis of a very informative discussion in which such subjects as cheapness, standardisation of experimental methods and test-pieces, and new developments all received consideration.

## DISCUSSION.

### Interpretation of Creep Tests.

DR. A. B. EVEREST (hon. secretary of the Branch) emphasised that foundrymen were intimately concerned with the problem of heat-resisting alloys, simply because castings must be used when one wanted to attain the highest strengths in materials at high temperatures. When one worked a steel or any other metal, one was essentially requiring it to flow. In the creep test, one was measuring the property of the metal to flow under load; in a high-temperature alloy, however, that was exactly the property which was not wanted. Looking at the problem from that point of view, it was clear that the heat-resisting alloy of the future had to be used in the cast form. Prof. Hanson had said that when once an alloy was worked, its natural crystal structure was changed and it was made relatively unstable, so that when it was subjected to high temperatures it would recrystallise and change its form—and any change in an alloy at high temperatures would generally result in a general weakening, and probably a disintegration, of it.

Discussing the variation of the strength of iron and steel with increasing temperature, he said that the strength-temperature curve of any carbon steel, or of a cast iron which had a pearlitic matrix, always showed a drop in strength at about 300 deg. C. Prof. Hanson had shown that the strength was good at 400 deg. C., and that it was reduced at higher temperatures; that was true, he believed, of most of the cast irons and carbon steels, but there was also the fact that in nearly all cases the strength at 300 deg. C. was very much lower than the strength at 400 deg. C., as indicated by the instantaneous break test. He asked, therefore, whether that feature of a regain of strength between 300 and 400 deg. C. was reproduced in a creep test.

### Theory of Growth.

With regard to growth in cast iron, he questioned Prof. Hanson's statement that the first cause of it was oxidation in the graphite plates, and said he would have thought, as did Prof. Sir Harold Carpenter and various others, that the first stage in the growth was the decomposition of the carbide when the temperature was within the critical range, resulting in the formation of a very coarse graphite; this was associated with violent volume changes in the metal, and the result of these factors was that the metal opened up and passages were formed through which oxidation proceeded into the heart of the metal. He pointed out that in the cast irons which Prof. Hanson had referred to as being heat resisting, *i.e.*, the high-silicon cast irons, and also in the austenitic cast irons, although the metal matrix might have a greater resistance to oxidation, nevertheless, the graphite was there, and yet the metal did not grow. That fact supported to some extent the suggestion that decomposition of the carbide was the first stage in the growth and that oxidation was a secondary factor.

Discussing the high-silicon cast iron developed by the British Cast Iron Research Association, he said he had been puzzled with regard to its mechanical strength. As the silicon content was increased, undoubtedly the metal had an improved resistance to heat, according to the findings of the Research Association, but, at the same time, if one continued to add silicon the metal lost mechanical strength and it became definitely brittle and unmachineable. Irons containing about 12 or 13 per cent. of silicon had been used for a long time, owing to their acid-resisting properties, but castings of this type of material were brittle and unworkable, and had very poor mechanical strength. So that there must be a compromise between resistance to oxidation and heat and mechanical properties, and he asked if Prof. Hanson could give an assurance that, so far, cast irons which represented a useful compromise had been developed.

Dr. Everest added that he was under the impression that the alloy with outstanding strength at high temperature was the 80/20 nickel-chromium alloy; curves which he had seen appeared to indicate that that alloy was much better than even the austenitic steels. He was also very interested to hear that the nickel-chromium-iron alloys, to which were added metals of high-melting point for the purpose of stiffening them up, were actually developing very high strengths. A strength of 6 tons at 800 deg. C. was truly remarkable. Finally, he asked if Prof. Hanson could confirm that "Brightray" had a strength much less than that of the austenitic materials.

### Chrome Additions.

MR. JOHN SHAW, after congratulating Prof. Hanson on his clear explanation of the causes of growth and distortion, said he was a little disappointed that the heat-resisting irons of the less expensive type had not been dealt with more fully. There were at least two commercial projects of primary importance at the moment which called for a material with good heat-resisting properties, but for which the material must be comparatively cheap. Prof. Hanson had dealt with the oxidation resistance conferred by chrome additions, and had suggested tentatively that they caused the formation of a thin and firm impervious scale which tended to resist further oxidation of the metal. If this were found to be correct at temperatures up to 800 deg. C. it was an important point. Unfortunately, the action of chrome additions to cast iron was not thoroughly understood, as was indicated by a case which had come to his notice. It was generally taken for granted, as the result of steel experience, that chrome did not enter into solution with the iron until its quantity was at least four times the carbon content. In the case at issue, two irons containing approximately 3.8 per cent. of carbon and 1 per cent. of chrome were cast into chill tests and castings. In one case the usual well-defined dendrites, vertical to the chill face, were present. The Shore hardness was 74. The other had the vertical dendrites for a depth of $\frac{5}{8}$ in., and then a series at right angles to the first, and parallel to the chill block. The hardness of the second was only 62 Shore. The two irons followed each other from the same cupola, and the only difference was that the metal in the first case melted hotter. Both were cast at the same temperature, approximately 1,270 deg. C. It might appear from this that the two carbides mentioned by Arnold and Read, viz., $Cr_3C_2$, which was very hard, and $Cr_4C$, which was much softer, might be present. Against this, however, there was the fact that the carbon and chrome was the same in both cases.

Mr. Shaw was very pleased that Prof. Hanson had emphasised the need for more careful and prolonged work on heat-resisting irons before conclusions were drawn. For instance, irons which had stood up well with $CO_2$ present had failed badly when $SO_2$ was added; yet this combination was present in many cases in industrial applications. He agreed with Prof. Hanson that to base conclusions on a few heats at one temperature was of little value. The increase of volume and weight was not regularly progressive, and all samples should be heated to the fixed temperature a sufficient number of times to ensure that equilibrium was reached and no further growth occurred.

### Standardised Surface Area Essential.

Another point which had not received the attention it merited was that of the great variety in sizes of test-pieces used. In considering the various investigations since Outerbridge, he had found that in nearly every case the size of the test-piece was different, the sizes varying from $\frac{3}{4}$ in. long and 0.6 in. dia. to 6 in. long and 1 in. dia., and an angle iron 6 in. × 4 in. × 2 in. × $\frac{3}{4}$ in. If it be granted that oxidation commenced from the outside and worked inwards, then the superficial area of the specimen in relation to the weight was of vital importance. If the specimens were sand-blasted after each re-heat, one obtained, at least for some time, a decrease in both volume and weight, due to the removal of the surface scale. If one had a cast bar turned to 1 in. dia., and cut two test-pieces from it, one 6 in. long and one 0.5 in. long, one had in the first case a superficial area (including that of the ends) of 20.4204 in., and a weight of 1.23 lbs. In the second the surface area was 3.1416 in., and the weight 0.103 lb. If in both cases the surface area were divided by the weight (20.4204 ÷ 1.23 lbs. = 16.6) and (3.1416 ÷ 0.103 lb. = 30.5) it was apparent that from the same iron, and applying similar treatment, the percentage increase in weight would be approximately double in the one case as compared with the other. It was time that a standard size should be adopted, therefore, for all investigations.

### How Creep Tests are Made.

DR. M. L. BECKER (National Physical Laboratory, Metallurgy Department), discussing the superiority of cast alloys over wrought alloys, said that he had noted that superiority in the case of the carbon steels in particular. He was not at all sure that it was due wholly to grain size, but it seemed that that factor had something to do with it.

As had been pointed out by Professor Hanson, the two most necessary properties in a material for high-temperature service were resistance to creep and resistance to oxidation. The importance of resistance to creep had been appreciated for a number of years, and a very well-defined technique had been developed for testing that resistance. It was quite a simple matter to place a test-piece in the machine, load it and allow it to remain loaded for a long time at a constant temperature; but a difficulty was that the time occupied by such tests was considerable. The fact that that method had been worked out was important, however, and there were upwards of 30 testing units at the National Physical Laboratory. On the other hand, he believed that very little had been done to evolve definite and reliable tests on resistance to oxidation. Some investigators had heated samples of metal in what they had called oxidising atmospheres—generally in a muffle,. but sometimes, perhaps, over a fire—but he felt sure that the results obtained by the different investigators would not bear comparison. A standard method was very much needed; work was being carried out at the National Physical Laboratory with this end in view, and it was hoped to evolve something approximating to standard conditions. The problem of oxidation seemed to be particularly important in relation to the relatively cheap materials, such as mild steels and cast irons—the materials of general construction. A designer might provide a good deal more than the required thickness of metal in a section in the first place, but if the material wasted away as the result of scaling, no matter what the creep resistance of the material might be, the stresses in that material would ultimately rise to such an extent that creep would occur. It was particularly important, therefore, to ensure the resistance of these materials to oxidation;

* See our issue of June 4, page 387.

but so far investigators had not been particularly fortunate, as far as he could see, because small additions of other metals to steel and other general materials of construction appeared not to have affected the rate of oxidation very considerably. He was hoping that something better would be found, however. He asked Professor Hanson if he considered that the addition of a layer of protective metal such as chromium or nickel on the outside would be effective; that had been done in the case of aluminium alloys, he believed, in order to guard against corrosion, and if it could be done in other cases also it would seem to be a step in the right direction.

With regard to the rather remarkable heat-resisting alloy which had been developed at the National Physical Laboratory by Dr. Rosenhain and Dr. Jenkins, he assured the members that this could be machined; he had not seen it machined, but had been told by those who had tried it that it was not very difficult to machine, provided the speed of cutting in the lathe was not high.

Professor Hanson said he supposed a Widia tool was used.

Dr. Becker agreed that it was a special tool.

### A Simple Appreciation of Creep.

Mr. C. Cleaver, commenting on Professor Hanson's remarks concerning iron and nickel, said he assumed that the iron referred to was commercially pure iron, containing perhaps 0.1 per cent. of carbon. Continuing, he said he had noted, as Dr. Everest had done, that the grey irons had suffered a distinct loss of strength at a temperature of about 250 to 300 deg. C., and he asked for information as to the cause of it. Again, he gathered that the flow to which Professor Hanson had referred was similar to that which occurred in lead when it was compressed, *i.e.*, that the particles strained over each other. Mr. Cleaver also asked if Professor Hanson could suggest why certain plates, about 8 in. square, $\frac{3}{8}$ in. thick and having a flange about 1 in. deep all the way round, cracked in some cases when subjected to high temperature. They were made of ordinary grey iron with a nickel-chromium addition—about 1.5 per cent. nickel and 0.35 per cent. chromium.

The Branch-President (Mr. A. F. Gibbs) congratulated Professor Hanson, not only because his lecture had been so illuminating, but also because it had been so inspiring, and he added that he hoped it would encourage many of the young men who had heard it to devote their energies to some of the research work which Professor Hanson had shown to be necessary. Discussing his own experience in the making of castings for high-temperature duty, he mentioned that on one occasion he had made some pump plungers in high-duty brass, in which he had used aluminium as a protective medium, and had added cast iron for strengthening purposes. These castings had been in use for about two years, and had given every satisfaction, except that when first put to use they had expanded; a certain amount of flow had occurred, due to high temperature. Consequently, when making a second batch, using the same mixture, he had annealed them, and they had given no trouble at all. He asked Professor Hanson whether the annealing had counteracted the flow.

### A Clutch-Plate Defect.

Mr. W. B. Lake said it had come to his notice that in clutch plates and brake drums, which were subjected to a good deal of pressure at a fairly high temperature—up to about 500 deg. C.—dark spots appeared frequently in the surfaces of the metal. These spots occurred on the part of the brake drum which came into contact with the brake lining, and in the parts of the clutch plates which came into contact with the other plates. Further, the occurrence of the spots was not confined to any one material; he had seen them in a 0.9 per cent. carbon steel, in cast iron, in ordinary common cast steel, and in all sorts of other materials, but he had never been able to obtain an explanation. He asked Professor Hanson if they were likely to be due to flow of the metal.

### AUTHOR'S REPLY.

Professor Hanson, replying to the discussion, said that when one tried to deal in a general and comprehensive manner with a subject such as he had dealt with, one had to make generalisations which, in a scientific Paper, one would qualify. It was undoubtedly true that a very great deal remained to be learned with regard to this particular subject, but if he had tried to state what that was, his lecture would have been very uninteresting. He thanked Mr. Dews for having drawn attention to the effect of molybdenum upon the strength of special steels. It was true that quite small amounts of molybdenum had a very pronounced effect upon such steels, and, indeed, it was rather unusual to find such a pronounced effect arising from the inclusion of such small quantities of an added metal.

He hoped he had not suggested that nickel would confer upon steel anything approaching immunity from oxidation. It reduced oxidation, sometimes to a small extent and sometimes to a greater extent, but nickel alone never conferred immunity upon steel. Indeed, he did not think any one metal conferred immunity.

With regard to testing, he said that work was proceeding with a view to devising a rapid form of test, which was very badly needed. He had been rather amused at Dr. Becker's description of a creep test. It was all very well to say that one placed a specimen in a testing machine and left it there for a time, but one might be excused for asking what could be done with the testing department while the test was proceeding. One required special testing machines of very great accuracy, and many of them, in order to make rapid progress; although the procedure might be simple, the footing of the bill was far from simple.

He was unable to offer off-hand an explanation of the occurrence of spots on the clutch plates referred to by Mr. Lake, though he might be able to do so if he had an opportunity of inspecting them.

Emphasising the importance to foundrymen of the heat-resisting alloy problem, Professor Hanson reiterated his belief that there is a great future for castings in these alloys. The making of them might be very difficult, but their use would be called for, and somebody would make them. Those already in the casting field must see to it that they were the people who would make the castings, and that they would overcome the difficulties inherent in their making.

### Tensile, Creep and Growth.

Replying to Dr. Everest's question concerning the reduction of the tensile strength of cast iron at a temperature of about 300 deg. C., he said that, so far as he was aware, there was no corresponding reduction in the creep strength. Further, that reduction of strength did not always occur in all irons. He could not say what was the cause of it. With regard to the cause of growth, he did not quite agree with Dr. Everest. The cause of the growth was internal oxidation. Decomposition of carbide might help in initiating it, but growth could occur in cast iron which had no carbide in it. The rapid heating and cooling was by far the most important factor; that operated by setting up internal stresses, due to the volume changes as the iron changed from the alpha to the gamma, and the grain was opened up and the oxygen from the air was allowed in through the spaces where the graphite flakes had existed previously. That was the mechanism.

For information concerning the high-silicon cast iron developed by the British Cast Iron Research Association, he referred Dr. Everest to the Paper read by Dr. A. L. Norbury (senior metallurgist to the Association) before the spring meeting of the Iron and Steel Institute.

The creep strength of the 80/20 nickel-chromium composition at 80 deg. C. was about 2 tons per sq. in. This was certainly one of the best of the commercial materials. He believed that one or two of the heat-resisting steels were equal, or slightly better, but the alloy which gave a creep stress of 6 tons per sq. in. at 800 deg. C., developed at the National Physical Laboratory, was not yet a commercial material.

Professor Hanson expressed regret that he had not been able to refer more than he had done to ordinary cast irons; in his lecture he had dealt principally with the higher ranges of temperature, and any attempt to deal with other materials would have involved opening up a very wide field.

After emphasising the point made by Mr. Shaw as to the importance of re-heating in experiments conducted with a view to arriving at a satisfactory heat-resisting alloy, he urged upon the investigators at the National Physical Laboratory that if they were seeking to devise a test (for oxidation at high temperatures) which would be of practical use, they should appreciate that re-heating was fundamental; any test which did not include many repetitions of heating was not likely to simulate practical conditions.

He was unable to say whether or not chromium could be built up satisfactorily as a protective layer on steel, and did not think that much success had been achieved in that respect, though aluminium had been used as a protective layer on iron and steel with some success. How far that form of protection would be permanent he did not know. He personally would prefer to have metal of uniform composition throughout, so that he would know where he stood.

Replying to Mr. Cleaver, he agreed that the flow he had referred to was similar to that which occurred in lead; the analogy was a very good one. He would attribute the cracking of the casting mentioned by Mr. Cleaver to internal stresses, which could be overcome by annealing. There was a much greater concentration of metal around the flange than in other parts, and the internal stresses would be rather severe. The same remarks applied to the pump plungers referred to by the Branch-President. The change of section was probably due to internal stresses, which had been relieved by annealing, which explained why the annealed plungers had not given the trouble that had been previously experienced.

## A New Section of the Institute of British Foundrymen Formed.

A new Section of the Institute of British Foundrymen was successfully inaugurated at a large meeting of foundry representatives held in Lincoln last month. This Section, to be known as the Lincolnshire Section, will be attached to the East Midlands Branch, and will cater for the needs of foundrymen in the Scunthorpe, Gainsborough, Lincoln, Newark and Grantham districts, as well as the smaller outlying areas.

The meeting elected the following officers:—Mr. J. Feasey, President; Mr. J. I. Coleman, Senior Vice-President; and Mr. F. S. Wordsworth, honorary secretary; the office of Junior Vice-President to be left open for the time being. The secretary, Mr. Wordsworth, 58, South Park, Lincoln, will be glad to hear from foundrymen in the area who are interested in the newly-formed Section.

**Sheet steel,** when it is pickled, absorbs a small amount of hydrogen. This can be liberated by leaving the sheets for some time in a bath of water. Steel can be protected from rusting by immersing it in a bath of water containing powdered lime and kept hot by steam jets. After a short immersion it should be withdrawn, and on drying a limey film will form which protects the steel from rust.

# Recent Developments in Cast Iron and Foundry Practice in Great Britain.

By J. G. Pearce, M.Sc., M.I.E.E.

(DIRECTOR, BRITISH CAST IRON RESEARCH ASSOCIATION.)

(*Continued from page* 438, *vol.* 44.)

### Growth- and Scale-Resisting Iron.

It is well known that cast iron, when subjected to prolonged heat, increases in volume, and this change is called growth. It varies according to whether the heating is in air or *in vacuo*, whether it is under oxidising or reducing conditions, or whether the temperatures are fluctuating and intermittent or regular and continuous, but it is experienced to a greater or lesser degree under all conditions.

For the past quarter of a century the compositions of growth-resisting irons have been derived from the classic work of Carpenter and Rugan, whose investigation was published in 1909. The broad conclusion from this work is that growth is due to the presence of silicon, and that consequently, to diminish growth, it is desirable to diminish the silicon content. It was shown that white irons grew very much less than grey irons, and the lower the grey iron with respect to the silicon content, the more satisfactory it became. There is no doubt of the correctness of this as far as it goes, and in ordinary irons the best for heat-resistance are those lowest in silicon. This state of affairs persisted until the end of 1928, and an excellent summary of the state of knowledge at that time is provided in the Association's Bulletin for April 1928. Later in that year discoveries made in the laboratories of the Association by Dr. A. L. Norbury and Mr. E. Morgan showed that it is possible to diminish the growth of grey cast irons below the best figures obtained from the very low silicon irons by the converse process of increasing the silicon content to above 4 per cent. This astonishing discovery has since that time been carried a good deal farther, and the first part of the scientific evidence respecting the superiority of the high silicon irons is contained in a recent paper by Norbury and Morgan.[1] It has given rise to a new series of heat-resisting irons covered by a British patent* and pending applications, and has also been covered in foreign countries. The Association considers every prospective application submitted to it by members and makes a recommendation with respect to the mixture and method of manufacture, according to the circumstances of each case, temperature, time, nature of heating and size and shape of the casting. Speaking generally, however, the compositions are about 5 per cent. silicon and upwards, but above 10 per cent. silicon the irons are difficult to machine.

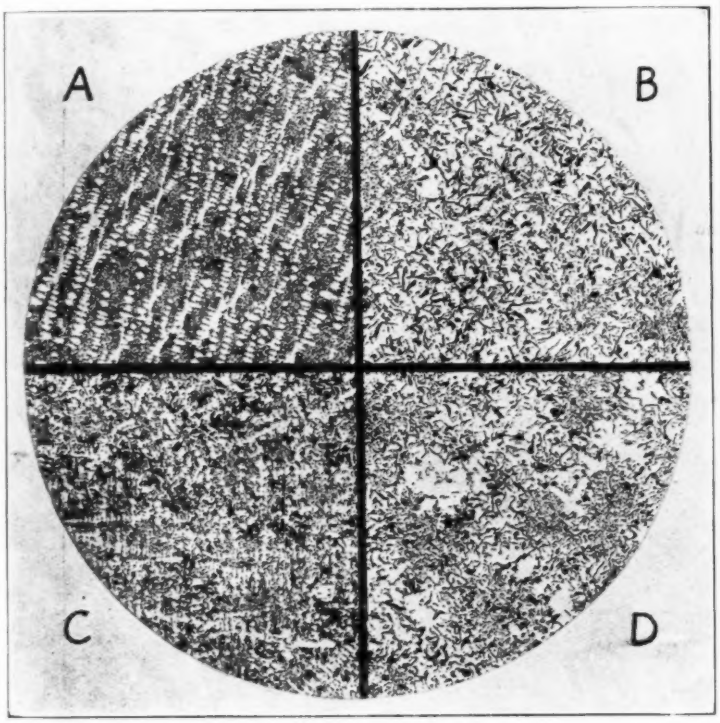



FIG. 3.—SILAL GROWTH- AND SCALE-RESISTING CAST IRON. (Unetched, × 50.)

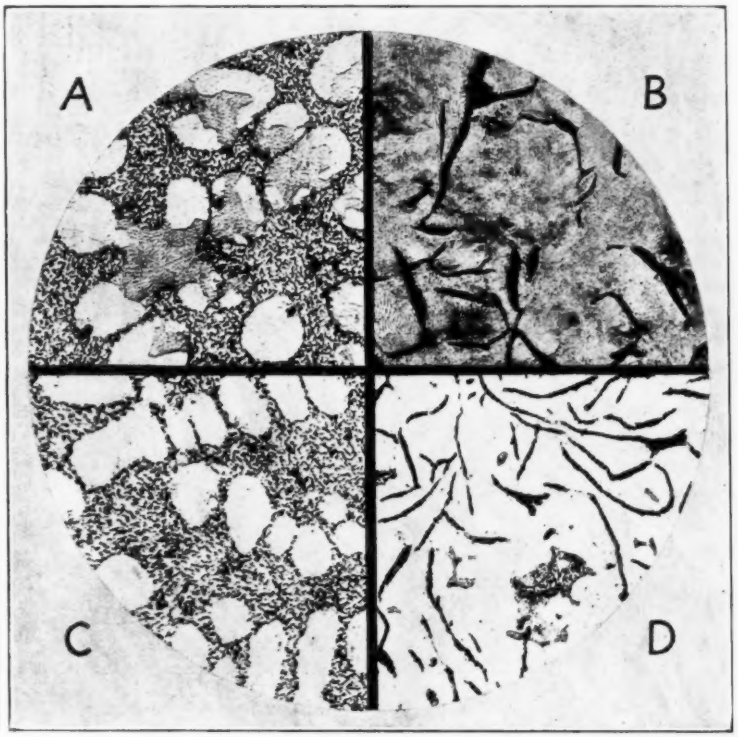



FIG. 4.—CAST IRONS OF SIMILAR COMPOSITION AND DIFFERENT STRUCTURES. (Etched, × 200.)

### Properties of "Silal."

These alloys have been registered under the trade name "Silal." The bulk of the Silal normally manufactured (by members of the Association) lies between 5 and 7 per cent. silicon. The carbon content is inevitably low in such an iron. A 2.5 per cent. silicon iron will naturally take up about 3.5 per cent. of total carbon in the cupola, while an iron containing less than this carbon content will usually tend to increase to that figure. At 5 per cent. of silicon, however, the corresponding carbon value is about 2.8 per cent. and at 10 per cent. of silicon about 1.6 per cent. At 15 per cent. of silicon the figure is about 0.8 per cent. The Silals are low in carbon and their growth-resisting properties may be ascribed to the following causes:—

(1) In a well-made Silal the basic structure of the metal is entirely ferrite and fine graphite, or at most contains a fine network of pearlite which disappears on the first heating. The first photomicrographs to be published of Silal are given in Fig. 3. Analyses of these and other irons referred to below will be found in Table I. Fig. 3A represents a section 0.125 in. thick of a commercial, cupola-made casting etched and shown at a magnification of 50 diameters, whilst 3B similarly represents a section of the same casting 0.25 in. thick; 3C is the ¼-in. section of a step-bar casting of Silal, and 3D the 1-in. section, also commercial material made in the cupola. In each case the centre of the section is shown. A faint pearlite network may be discerned in 3C, but normal Silal is ferrite-fine graphite. The graphite size may be usefully compared with that shown in a good engineering iron of the same magnification in Fig. 5. The bulk of ordinary engineering irons are pearlitic in character, and the break-down of the carbide of the pearlite is only a question of time and temperature, unless stabilised by chromium, the addition of which is limited if machinability is required. When a fully pearlitic iron is converted to the fully ferritic-condition by heat, the increase in volume is about 2 per cent. In ferritic Silals, however, there is no combined carbon to graphitise on heating, and consequently no growth from this cause.

(2) Ferrous alloys, when subjected to heat, invariably form on the outside a coating of scale or oxide. Frequently this friable scale will peel or fall away, and expose a further surface to oxidation, the process thus going on until all the iron has been oxidised. The formation of iron oxide involves considerable volume increase, which represents the final part of the growth phenomenon, the first stage of which is the conversion of iron carbide to iron and graphite

* British Patent 323,076.

(see above). In the case of ordinary cast iron, the presence of graphite cavities offers to the oxidising gases a series of channels into which they penetrate and cause oxidation to proceed to the inside. This not only produces of itself a partial increase in volume, but the resulting internal pressure yields minute cracks in the interior, which again increase the area for gaseous attack, and the process goes on continuously. Scaling and growth, therefore, represent the external and internal phases of the one phenomenon. Silal, when properly made, contains nothing but extremely fine graphite, so that there is practically no entry offered to the oxdising gases. It is also known that silicon in solution in iron increases the scaling resistance of the material, as is shown in the case of the silicon steels, and the present discovery has reconciled the whole of previous experience with cast iron with experience on steel. It was previously impossible, on account of the apparent contradiction of heat-resistance requiring high silicon for steel and low silicon for cast iron, to reconcile the two on any rational basis. Reference

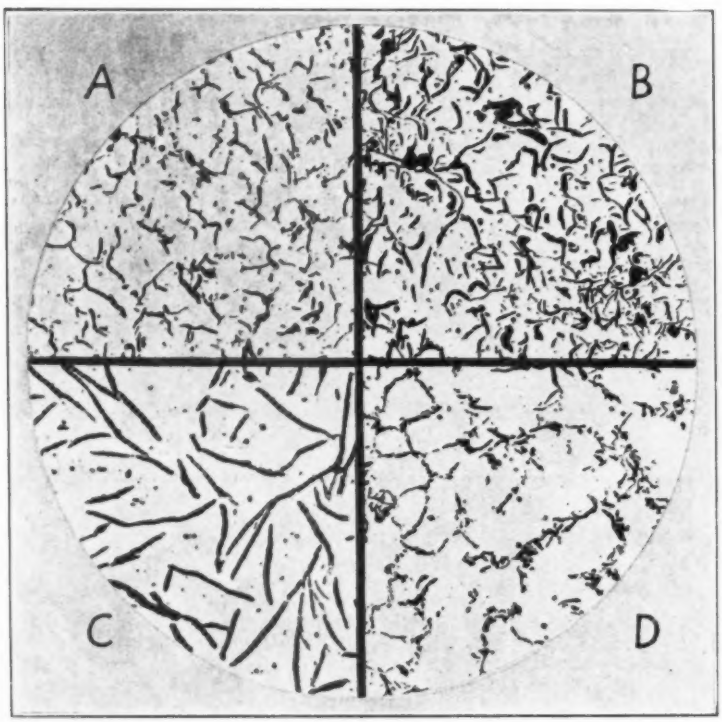



FIG. 5.—GRAPHITE STRUCTURE OF GREY IRONS.
(Unetched, ×50.)

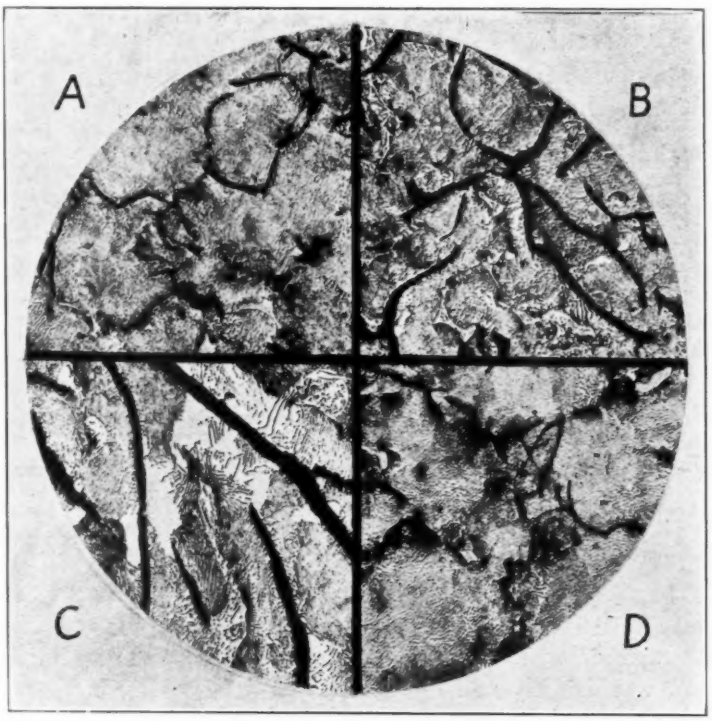



FIG. 6.—PEARLITE STRUCTURE OF GREY IRONS.
(Etched, × 200.)

is made below to further researches showing that there is a tendency for fine graphite to be associated with ferrite in the casting, and normal graphite of the flake type to be associated with pearlite. If the melting conditions cause the production of flake graphite, even the Silals will contain pearlite. It is scarcely necessary to add that pinholes, blowholes and other gaps in the structure, due to gases or other causes, must be avoided, as they are far worse in their effect than graphite cavities, being larger and offering an extended area for attack.

(3) Silicon in solution in iron raises the pearlite change point, or the point at which graphite will dissolve on heating, and be redeposited on cooling. It is obvious that any ordinary cast iron required to withstand heat will not last very long if it is called upon to be heated beyond the pearlite change point, as every time it is cooled down, a little more permanent growth takes place. Silicon, however, raises this point very markedly, and the change point on cooling, rises from about 685 deg. C. at 2 per cent. silicon to about 1,000 deg. C. at 7.5 per cent. silicon. In these problems it is often the last 50 deg. C. or so that counts, and the beneficial use of high silicon enables a much higher temperature to be withstood without taking the metal into the danger zone.

The advantages of silicon have thus been used in Silal in every possible way, and the disadvantage, that of its graphite-coarsening action, is rendered negligible by the particular method of manufacture adopted, which induces a very fine state of division in the graphite. The discovery has recently been confirmed in Germany, but it is interesting to note that from various parts of the world Papers are still being received from various investigators showing that silicon is bad in heat-resisting irons. A German Paper, published in October, 1930, analysed about twenty important contributions to this subject from all parts of the world, and showed that nobody regarded silicon as beneficial, and a few considered silicon as neutral, while the remainder were overwhelmingly inclined to regard it as detrimental in causing growth.

This investigation forms an excellent illustration of the general principle that the way of true advance lies through understanding what is going on in the metal and that progress is achieved by working with and understanding natural laws. Empirical attack on a problem by the method of trial and error occasionally gives a fortunate result, but it does little to contribute to real understanding, and scientific control ultimately is bound up with a knowledge of what is happening. The Association never seeks to apply empirical knowledge to foundry problems, but to work on a proper metallurgical or technical basis.

### Mechanical Properties of the Silal Irons.

While tensile strengths of the order of 10 to 16 tons are usual with this material on standard test-bars, there is no doubt whatever that silicon in solution hardens the material, and hence the ordinary Silals are not so good mechanically as the best engineering irons. Alloy types are being developed. Thus, on a Silal step-bar casting, on the ¼-in. section, the Brinell hardness was 241, and on a 1-in. section the Brinell hardness was 209. In a ferritic iron containing 2 to 2.5 per cent. silicon, the Brinell hardness would be about 180. The Association does not recommend this material for engineering castings for prime movers, as it believes the growth problem is solved so far as this purpose is concerned, and requirements can be met satisfactorily by the high-quality engineering irons. The new material is being applied particularly to such castings as firebars, stoker links, furnace castings, melting pots, retorts and the like. It is easily machinable up to the silicon limit mentioned above, and does not present any difficulty in the foundry if reasonable care is taken and experience available is used.

Tests which have not yet been published have shown that at 850 deg. C. the high-silicon irons are stronger, that is to say, they deflect less rapidly under load than low-silicon irons, such as high-quality engineering irons. There is no need to repeat scientific evidence, which has already been given elsewhere,[3] as to the growth-resisting and scale-resisting properties of Silal irons. For example, a 7 per cent. silicon iron, after heating to 850 deg. C. for eight days, was virtually unscaled, while a 2 per cent. silicon iron, after heating to the same temperature for six days, was coated with scale about $\frac{1}{20}$ in. thick, and oxidised iron about $\frac{1}{10}$ in. thick.

The Association has very high regard for the heat-resisting properties of the low-silicon irons, and frequently recommends them, with or without chromium, when the circumstances warrant it. These types each find their own field of application. Particularly successful results have been obtained with nickel-chrome low-silicon mixtures on retorts for low-temperature carbonisation.

### Conditions of Melting and the Germ Theory.

The Association has played considerable part in developing what may conveniently be termed the germ theory of cast iron, in accordance with the policy indicated above, that an understanding of what is happening in this complex material is likely to lead us further in the direction of scientific control of cast iron than results

achieved by trial and error methods. Such an understanding also illuminates the path the investigator has to travel. One of the most baffling phenomena the founder has to face is the variation in properties of cast iron, even when he has, as far as is humanly possible, kept everything the same with respect to raw material, manufacturing conditions and labour. It has been shown by Continental investigators that, when cast iron is heated well above its ordinary melting temperature, the graphite in the casting is obtained in a finer state of division. The term "superheating" is often loosely used to mean heating above the melting point, but every cast iron has to be superheated before it can be cast, because it must be melted to a temperature well above its freezing point. Superheating, however, implies melting to, say, 100 or 200 deg. C. higher than ordinary foundry-melting temperatures. Experiments carried out by the Association[4] in the crucible showed that it is possible from the same composition of iron to make two entirely different structures, the one consisting of ferrite and very finely-divided graphite, a structure unfamiliar to most people in cast iron, and the other containing the ordinary familiar pearlite—normal-graphite. Fig. 4 has been previously published, but is reproduced for reference; 4B shows the ordinary pearlite—normal-graphite structure of cast iron, and 4A shows at the same magnification a structure of ferrite—fine-graphite obtained from a composition very similar to B. Fig. 4D shows the ferrite—coarse-graphite structure which would be obtained in an ordinary foundry iron with relatively high silicon or very slow cooling, and 4C represents a similar mixture to D, showing only ferrite and fine graphite. Special attention is drawn to 4A and 4B as representing strongly-contrasting structures of ordinary cast-iron composition. These two structures gave remarkable mechanical, physical and founding differences. The pearlite—normal-graphite (4B) has the ordinary steel-grey appearance and hardness of foundry iron, but the ferrite—fine-graphite iron (4A) is finer in texture and darker in appearance to the naked eye. It is also very much softer and much more easy to machine, since it contains very little combined carbon. The two types do not show very marked differences in their tensile or transverse strength when properly made. Both are good, although the fine-graphite iron shows the differences which might be expected from a softer material. The mechanical properties are shown in Table II. In the ordinary way, an iron consisting wholly of ferrite—fine-graphite contains very low combined carbon, such as the 0.14 per cent. shown in Fig. 4C. Frequently, however, an iron structure appears as a mixture of ferrite—fine-graphite and pearlite—normal-graphite, with the result that the combined-carbon content determined by analysis is the average of that obtained in the two structures. This average is useful as an index to the amount of each present. This actually happened in the bar shown in Fig. 4A. While parts of it were as shown, other parts were pearlitic, and the combined-carbon content, 0.62 per cent., indicates the extent of the mixture.

While the pearlite iron, pipes or "feeds" in the ordinary way and shows the usual sinking in runners and gates, the fine graphite type finishes practically flush and level in the riser. Another singular difference between the two is that the fine graphite type requires much more silicon to keep it grey. Thus a 1.2-in. sand-cast bar of pearlite—normal-graphite with 3 per cent. total carbon will be just turned grey with 0.85 per cent. silicon, whereas the fine graphite type requires about 1.25 per cent. silicon. It is believed that the phenomenon of inverse chill appears when patches of this fine graphite structure occur in a casting which had not sufficient silicon to keep it grey, although there is ample to soften the remainder of the metal of the usual pearlite—normal-graphite type. It must be emphasised that these two types of structure can be had from identical compositions, and it has been proved possible to take an ordinary pig-iron, to melt it and cast it in the fine graphite form and then to remelt it, and, after suitable treatment, to recast it in the normal graphite form.[5] The difference, therefore, does not depend on chemical composition, and the question arises: To what is the difference due? In adopting the germ theory as an explanation, the Association is merely using a working hypothesis which so far explains these effects most satisfactorily, but which is known to be incomplete in certain respects. The germ theory will, without hesitation, be abandoned when a more satisfactory explanation is available. Very briefly, it is believed that the ferrite—fine-graphite structure appears when the metal solidifies free from the presence of fine graphite-particles in the melt, whereas the pearlite—normal-graphite structure appears when the metal has graphite particles present undissolved when the metal is molten. In the latter case the flakes are made by building up on the nuclei which are there in the first place. The experiment related above regarding pig-iron was carried out by melting the pig under such conditions that all the graphite flakes were removed, when the metal solidified ferrite—fine-graphite. After remelting the graphite particles were restored artificially, when the metal solidified pearlite-flake graphite. The process of putting graphite back into the melt is conveniently referred to as "inoculation," and this method may be responsible for important commercial developments. Figs. 4A and 4C were melted under such conditions that the melt was free from graphite nuclei, while in 4B and 4D they were present.

The process of superheating is one method of increasing the extent to which the graphite is dissolved, and if applied long enough and at a sufficiently high temperature, will enable the whole of the graphite to go into solution. Under such conditions superheating yields the supercooled or ferrite—fine-graphite structure, which is not usually desirable in the foundry, when mixed with pearlite, as is usual with cupola melting. On the other hand, superheating may, if carried out to a limited extent, diminish the size of the nuclei in the metal without eliminating them, with the result that the ultimate graphite size in the casting is diminished. It is obvious that superheating entails risks if it is carried to the point at which the graphite completely disappears, whereas the risks attendant on indiscriminate superheating can be offset and mitigated by the artificial inclusion of graphite at a later stage, that is, by inoculation. It has not been found necessary to superheat in order to get rid of graphite. In laboratory experiments it is possible to clear a melt of graphite by stirring it with a steel rod or by stirring in some finely-divided steel turnings. There would appear to be a possibility of producing controlled cast iron by the complete removal of graphite by superheating or other devices, and by the mixing in of a suitable inoculating material calculated to yield pearlite with graphite in as fine a condition as is consistent with the production of pearlite. It is particularly important to note that fine graphite tends to be associated with ferrite, whereas normal flake graphite tends to be associated with pearlite, and the dividing line which, of course, will vary to some extent according to casting thickness and other factors, appears to be reached with a flake length of about 0.02 mm. It has been possible, however, by various methods to ensure the production of pearlite in mixtures containing graphite below this size.

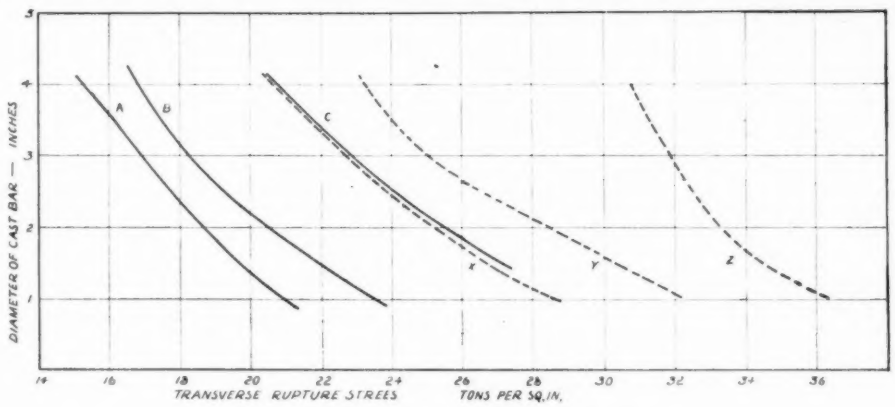



FIG. 7.—SIZE-STRENGTH CURVES FOR PIG-IRONS.

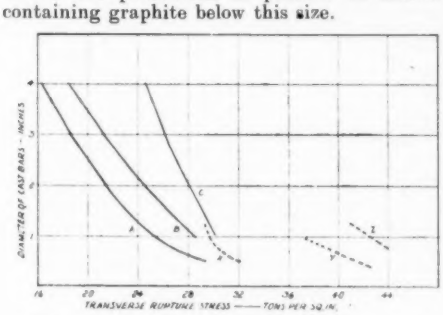



FIG. 8.—SIZE-STRENGTH CURVES FOR CAST IRONS, BOTH ORDINARY AND INOCULATED.

If the above theory is correct, it is fortunate for the foundry that under ordinary conditions of melting, the time of passage through the cupola and the temperature reached are insufficient to dissolve the whole of the graphite present in the pig and scrap of the charge. Obviously, the larger the graphite (that is, the coarser the structure in the charge) and the less efficient the cupola, the less likely is the graphite to dissolve completely. Hence the importance of cupola melting in the production of good cast irons. Melting temperature appears to be a matter of very much greater importance than pouring temperature.

### Silicon No Criterion of Strength.

It has long been evident that some modification is required of the conventional theory of the graphitisation of cast iron by silicon. Cast irons of similar mechanical properties and similar sections are found in practice to contain widely differing silicon contents. Conversely, irons of the same silicon content have widely different properties. The author recently compared the silicon contents of a series of irons cast in the form of bars 1.2 in. in diameter, some English and some German. The tensile strength of something like eighty different mixtures varied from below 8 tons per sq. in. to about 21 tons per sq. in. The silicon contents varied from 0.6 to 2.75 per cent., and there was no relationship whatever between silicon content and strength. In fact, the irons of the lowest and highest ten-

sile strengths mentioned had about the same silicon content, 2.75 per cent., and the iron of lowest silicon content mentioned had about 15 tons tensile. The remaining figures were scattered over the whole field. The germ theory not only lays stress on the carbon content, which obviously affects the issue, but upon the way the carbon content, both in quantity and distribution, is affected by the conditions of melting. The successful working out of this theory lies at the root of the possibility of producing controlled cast irons, that is, irons whose mechanical properties can be predicted in advance from the composition and conditions of melting. Fig. 5 shows the graphite structure of two irons in a composite microphotograph (×50), showing at 5B and 5C the graphite structure of an ordinary cupola-melted iron from ordinary charges, but of good quality. Fig. 5B is from the middle of a 1.2-in. bar, and 5C from the middle of a 4.2-in. bar. Figs. 5A and 5D show similarly the graphite structure at the centres of 1.2-in. and 3.2-in. bars of an inoculated iron, that is, an iron which would, and in fact did, cast white, but which was rendered grey by the addition of a suitable graphite-provoking agent. Figs. 6A and 6D (×200) show the etched structure corresponding with 5A and 5D, and 6B and 6C similarly show the etched structure of the ordinary iron, corresponding with 5B and 5C. It will be noted that there is much less distinction between the graphite size of the two sections of inoculated metal than between the two sections of ordinary cupola-melted metal.

TABLE I.—*Chemical Analyses of the Irons Shown in Figs.* 3, 4, 7 *and* 8.

| Fig. | T.C. | C.C. (1.2-in. Bar.) | G.C. | Si. | Mn. | S. | P. |
|---|---|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| 3A-3B | 2.5 | — | — | 6.5 | — | — | — |
| 3C-3D | 2.7 | — | — | 5.3 | — | — | — |
| 4A | 2.91 | 0.62 | 2.29 | 1.82 | 0.67 | 0.03 | 0.03 |
| 4B | 2.94 | 0.80 | 2.14 | 1.70 | 1.00 | 0.03 | 0.03 |
| 4C | 2.81 | 0.14 | 2.67 | 4.53 | 0.98 | 0.03 | 0.03 |
| 4D | 2.71 | 0.17 | 2.54 | 4.46 | 1.10 | 0.03 | 0.30 |
| 7A | 3.55 | — | — | 1.95 | 0.50 | 0.08 | 0.72 |
| 7B | 3.71 | — | — | 1.29 | 0.62 | 0.09 | 0.59 |
| 7C | 3.50 | — | — | 0.68 | 0.35 | 0.18 | 0.64 |
| 7X | 3.25 | — | — | 2.16 | 0.92 | 0.12 | 0.38 |
| 7Y | 3.09 | — | — | 1.68 | 1.23 | 0.09 | 0.53 |
| 7Z | 2.97 | — | — | 1.01 | 0.71 | 0.12 | 0.26 |
| 8A | 3.16 | — | — | 2.06 | 0.39 | 0.14 | 1.12 |
| 8B | 3.24 | — | — | 1.41 | 0.56 | 0.10 | 0.55 |
| 8C | 3.42 | — | — | 1.17 | 0.39 | 0.13 | 0.60 |
| 8XY | 2.93 | — | — | 0.76 | 0.44 | 0.09 | 0.29 |
| 8Z | 2.5 | — | — | 0.68 | 0.15 | 0.04 | 0.05 |

### Fracture.

It will be evident from what has been said above that irons of similar composition may differ totally in fracture either with respect to the difference between the fine-graphite and flake-graphite types, or in the pearlite-flake-graphite range itself, as between the larger and smaller flakes. This work has, in fact, shown scientific evidence for the preference the British founder has always displayed for judging metal by fracture, for the Association has shown that what is called the fracture of iron, whether pig or cast iron or malleable iron, is due to the size and distribution of the graphite flakes it contains, and the whole of the conclusions drawn from the germ theory can be expressed in terms of fracture. Thus, if a foundryman wishes to open the grain of his castings, he includes in the charge pig of a lower grade number, that is, a pig containing coarser graphite. Conversely, to close the grain, he includes an iron with a closer fracture or higher grade number, and so on. The whole of ordinary experience in fracture can be restated in terms of the germ theory.

### The Strength of Cast Iron in Relation to Design.

British Engineering Standards Specification 321 of 1928 revolutionised the testing of cast iron in this country. In this first general B.E.S.A. specification ever devoted to iron castings, the round test-bar was adopted as standard, and the section of the bar was varied according to the thickness of the casting it was required to represent. The Association immediately concentrated on the round bar for experimental work, which it had already proved to be more satisfactory in many respects than the rectangular bars, and an investigation was begun with the object of ascertaining the relationships between the various mechanical tests, since, if the tests can be related, their variety can be reduced and the cost of testing diminished. Secondly, it was desired to ascertain the relationship between the strength of test-bars and the strength of castings varying in section. The work so far done on this has shown that tensile, transverse and compression tests substantially measure the same property of cast iron,[6] and that, given one test, the remainder may be estimated to a reasonable degree of accuracy for the same iron. For purposes of this comparison it is necessary to express the transverse test as a rupture stress in tons per sq. in.[7] The transverse strength is then about 1.8 to 2.2 times the tensile, and the compression strength about 4 times the tensile strength. It has also been shown that the strength of cast iron (tensile, compression and transverse) varies continuously with section,[6 8] that is, the strength is least in thick sections, and the change is a regular one until the thinnest section is reached, at which the metal remains grey. White iron is very strong, but its brittleness is a disadvantage, and this renders the strength properties very erratic. For a given series of mixtures in the same foundry, that is, under the same melting conditions, the series containing the higher silicon will be weakest and the least silicon strongest within the given range. For bars of a given size produced under the same melting conditions, the highest silicon is the weakest and the lowest silicon strongest, also within the grey range. It has been shown that detailed relationships between various mechanical tests, such as transverse-tensile, transverse-Brinell, etc., are only true for one particular set of melting conditions, that is, one particular foundry, but these relations, while not generally valid, are useful to a foundry for its own purposes, as changes in them show the effect of changes in melting practice. It should be borne in mind that a thick section of cast iron is relatively weaker than a thin section by virtue of the fact that the slower rate of cooling permits the growth of an increased graphite size, and in addition there is what may loosely be described as the effect of grain size to be taken into account. A problem yet to be solved, however, lies in the relationship between these properties and abrasive wear, hardness and machinability, and particularly the relationship of these three properties among themselves.

Few founders appreciate the enormous effect on the strength of the casting of the size and distribution of the graphite, or how easily this size and distribution is affected by changes in pig-iron or coke or scrap, and it should be borne in mind that these changes take place even when the material is chemically controlled and composition remains within the usual limits. Analysis is not a complete guide to the properties of grey iron; structure is equally important.

Fig. 7 shows the way the strength increases as the size of the bar tested diminishes for three remelted pig-irons, A, B and C, of varying silicon contents. In the same figure are given strengths of three pig-irons of lower total-carbon contents, X, Y and Z, from which it may be concluded that a diminution of the total carbon tends to push the size-strength curve bodily to the right. The analyses for these irons are given in Table I, and it is interesting to compare the analyses of C and X, shown by the chart to have very similar strengths in the same size of bar.

In Fig. 8, curves A, B and C refer to three cast irons melted in the same foundry under the same conditions, but from differing mixtures, C being the best quality and A being of ordinary quality. For purposes of comparison, X shows the strength of an inoculated iron suitable to replace C, Y shows the strength of the white iron bars, which were poured from the same metal as X before inoculation took place, and Z shows another experiment on an inoculated iron with a different base, having with the inoculent a ferro-alloy addition to raise the silicon content to 1.7 per cent. and the manganese to 0.7 per cent.

TABLE II.—*Mechanical Properties of the Iron Shown in Fig.* 4.

| Fig. | Transverse Tons/sq. in. (1.2-in. Bar.) | Tensile Tons/sq. in. (1.2-in. Bar.) | Brinell. (1.2-in. Bar.) | Repeated Impact (0.875-in.. Bar.) |
|---|---|---|---|---|
| 4A | 23.1 | 14.4 | 207 | mottled |
| 4B | 39.8 | 23.4 | 241 | 3,476 |
| 4C | 34.6 | 19.6 | 235 | 235 |
| 4D | 25.3 | 12.8 | 178 | 150 |

The analyses given in Table I on 8X and 8Z are of the base metal prior to inoculation. The inoculant does not materially raise the silicon content.

### Malleable Cast Iron.

The bulk of the work done by the Association on malleable iron has consisted in an examination of the effect of elements of composition, carbon, silicon, manganese, etc., on the mechanical properties of the annealed white-heart material.[9 10 11] Incidentally, it may be added that the effect on properties of all the ordinary elements of grey cast iron has been very fully determined, including the effect of some of the better-known additions, such as nickel and chromium, over a range far beyond that used in ordinary practice, several interesting irons of novel properties having been discovered. This work has paved the way for what may be the next main problem in cast metals, and that is, the problem of shrinkage and contraction, which is shown in such troubles in practice as porosity, openness of grain, draws and so on. The question of what test results may be expected from malleable iron depends normally on the test-bar chosen, particularly with white heart, and the Association is at present engaged in determining the most suitable size and shape and what thicknesses most appropriately represent particular thicknesses of castings.

The distinction which existed at one time between white heart and black heart is gradually being obliterated, and the time may not be far distant when it will be necessary to consider malleable iron on its merits entirely from the point of view of mechanical properties, and without regard to a particular process of manufacture concerned.

### Recommended Methods of Examination.

One of the difficulties which confronts the Association from time to time arises from differences in analyses reported by different labora-

(*Concluded on page* 27.)

# The Relationship Between the Engineering and the Foundry Trades.*

By L. H. Pomeroy, M.I.Mech.E., M.I.A.E. (Managing Director of the Daimler Company, Limited).

The author feels some considerable diffidence in presenting this Paper for the reason that his own experience is as specialised as that of his audience is universal. However, testimony from experience is about as useful a contribution as can be made to any discussion, so that the author proposes to deal with the subject from the viewpoint of one who has been intimately concerned with the design and production of motor cars in this country and the U.S.A., and with more than a nodding acquaintance with American foundry practice.

### Characteristics of Automobile Engineering.

Automobile engineering is characterised by several features which do not apply to mechanical engineering in general. A motor car is a mass-production product, representing a great deal of highly-stressed mechanism packed into a very small space; it is essentially a development of the last twenty years by engineers devoid of the least respect for precedent and incapable of taking "No" for an answer, whilst not only is the product such that it can be made throughout by unskilled labour, it usually is used by people as unskilled as those who produce it. Further, in no branch of engineering does a new idea progress from laboratory to practice more rapidly, nor is there a higher standard of manufacturing excellence combined with cheap production. There is probably no detail, be it tyres, wheels, springs, valves, sparking plugs, electrical equipment, brake linings or any of a myriad others, to which many men may not profitably, and in fact of necessity, devote their whole lives in order that the motor car may be the ubiquitous instrument of modern civilisation it has now become.

The motor car is essentially a mechanism in which the greatest result is required from the minimum weight of material. This desideratum acts in two ways. First, weight reduction, other things being equal, means cost reduction; second, engineering skill is proportional to the successful use of low factors of safety. Thus, economy and effectiveness go hand in hand. But as soon as the beaten path is departed from in engineering or anything else, a great responsibility for the results of such departure arises, so that progress must be achieved by persistent experiment and research, and thus more or less automatically becomes the business of experts and specialists.

Unfortunately, whilst a specialist may know all there is to be known about his own subject, he is rarely familiar with any other problems than his own, whilst the man who knows a little about everything is commercially dangerous. In this tendency to develop, some men who tend to know everything about nothing and others who tend to know nothing about everything, lies one of the dilemmas of modern industry. Somewhere or another in each motor manufacturing organisation there has to be an intermediate type of man whose duty it is to weld the often-conflicting ideas of the specialists.

### Correlating Design and Ease of Production.

Not the least of the problems with which he is faced is the co-relation of the engineering department and the foundry, either within or without the gates. It is the author's experience that there is at least as much, if not more, lack of understanding between the engineering designer and the foundry people as between any other of the specialists involved, for the reason that the design of even a simple casting presumes a definite knowledge of foundry practice on the part of the engineer designer which he frequently does not possess through lack of foundry training or opportunities for observation.

As things stand, it is, in general, not possible for the designer to acquire the necessary information, so that it is imperative for the foundry end of a design to be developed in consultation with foundry experts. It is here that trouble begins. Not only are some designers resentful of being told that an apparently clean and beautiful piece of design cannot be produced either with or without the aid of silicious gymnastics, but often, where outside foundries are concerned, they are so anxious to get orders that work is undertaken which is doomed at the outset to a high percentage of waste and loss to both customer and supplier. A further difficulty is that foundry experts are often very clever men who can make outrageously complicated castings and thereby set up precedents in which commercial considerations are sacrificed to a technical *tour de force*.

MR. L. H. POMEROY, M.I.MECH.E., M.I.A.E.

*(A biography of Mr. Pomeroy appeared in our issue of June 11, page 396.)*

### Clear Articulation—a Pre-requisite.

The remedy is for the designer to bring in the foundry expert at the very outset of the design. And by foundry expert is meant a man who not only knows his job, but can express intelligently the reasons for his views. It is well worth the while of foundries supplying the motor trade to train some thoroughly practical man in the art of expressing himself clearly, as well as acquiring a knowledge of cognate practice; in brief, himself a specialist. Not only is this desirable and necessary in order that new designs may proceed on practical lines, but also as a means for bringing to the notice of the designer the latest foundry practice, both in respect of materials and methods. In saying this the author is presuming that the motor-car factory is not the only place in which progress is constantly taking place.

### Specialists Should Advertise.

So far as developments in foundry practice are concerned, the knowledge of these seems to be kept as strict foundry secrets. One of course does not look for much aggressive advertising in an industry using, in the main, the methods of an ancient past, but surely there is some way in which modern foundry practice and possibilities may become as much a part of the mental equipment of the engineering department as that relating to machine-tool practice. It is not possible, of course, for every foundry to follow the methods of the nickel companies, but most foundries have some speciality which is worthy of commercial exploitation, some feature in which, by force of circumstances, they have become specialists, yet have not realised that in all arts and crafts the rewards of the twentieth century go every time to the specialist and not to the general practitioner.

Speaking as one who has been more intimately concerned with large foundries than most engineers, and who is naturally interested in foundry practice, very little information relating to automobile practice seems to be available without digging deeper than the ordinary engineer is prepared to do. It is suggested, therefore, that the publicity and sales methods of other businesses might well be studied by the foundry industry and accepted as a part of modern foundry business organisation. The essence of the matter from the foundry viewpoint is "Does the engineering department know what we can do, and does the purchasing department know of our existence?"

### Poor Progress in Strength of Grey Iron.

As things are now, the engineer is apt to feel like Watt's manager, Murdock, who had to spend two evenings with Murray "and by virtue of a plentiful dose of ale succeeded in extracting from him the arcana and mysteries of his superior performances." These words, written 150 years ago, reflect the verbosity of the times. Nowadays engineers are too hard-bitten to take much stock in glittering generalities, and the foundry sales appeal must be made in terms of hard facts and intimate details. Successful practice is the sum of perfected detail, and whilst recognising that progress in the ferrous-casting trade has been made in the last twenty years, one is forced to conclude that either ferrous-foundry practice has been for many years nearly perfect, or that, judged by other branches of engineering, it has a long way to go. For example, twenty years ago the best performance of a petrol motor was about 20 h.p. per litre of cylinder capacity, whilst now 100 h.p. per litre can be obtained; pneumatic tyres will now last 15,000 miles compared to 6,000 miles then; yet one looks in vain for corresponding improvements, metallurgical or otherwise, in any of the ferrous castings used in a motor car.

In Dickenson & Jenkins' "Watt and the Steam Engine" it is stated of tests on the strength of materials, carried out in August, 1783, that "A bar of cast iron was supported by two supports 2 ft. distant from each other and in the middle were suspended weights—

| | | |
|---|---|---|
| 1st Experiment. | Bent about ⅛ in. with | 4 cwts. |
| | Broke with | 12½ cwts. |
| 2nd Experiment. | Bent ¼ in. with | 10 cwts. |
| | Broke with | 11¼ cwts. |

From these figures the modulus of rupture of Watt's cast iron was 22.5 and 21.2 tons per sq. in. respectively. The minimum transverse strength of the A.S.T.M. arbitration bar, 1¼ in. dia., 15 in. long, as revised in 1918, for sections between ½ in. and 2 in., is 2,900 lbs., corresponding to a modulus of rupture of 20.3 tons per sq. in. It might be too severe to say that these figures represent the progress, or lack of it, made in 135 years, but, given that the

* Paper read before the Birmingham Convention of the Institute of British Foundrymen.

tests made by James Watt were reasonably accurate, there seems but little alternative.

This view is supported by tests made by your President (Mr. A. Harley) on cast-iron bars cast by himself, which give a modulus of rupture of just under 27 tons per sq. in., the test-bars being of the same dimensions as those used by Watt. This improvement, however, may be due to the "arcana and mystery of his superior performance."

### Non-Ferrous Achievement.

In non-ferrous castings, however, particularly in the aluminium and magnesium alloys, very definite improvements have been made, and the author would specifically mention the most excellent work now being done in connection with magnesium-base alloys, a recognition which is none the less sincere by virtue of his intimate association with similar work in the U.S.A. But in this case the excellence of the result seems to be due to the difficulty with which it was achieved. Possibly, if the engineering trades began to insist upon apparently unreasonable and impossible specifications of castings in general, progress in combining higher physical tests with better machining qualities, improved resistance to wear and corrosion and reduced weight and cost might soon follow.

### A Suggested Experiment.

Whether these come because of demand by engineers or competition amongst foundries or foundry research, or the universal stimulant of industrial depression, only time will tell, but they are long overdue. In any case, a good deal depends upon a proper understanding of both the foundry and engineering aspects of any proposed development. Take, for example, one item —resistance of cast iron to wear. There is no settled opinion amongst users as to the extent to which this (say, in a motor cylinder) is affected by the hardness or softness of the iron used, nor can there be until the conditions of lubrication, *i.e.*, the engineering aspect, are strictly defined, but there is no reason why foundrymen who make motor cylinders and drive motor-cars cannot fit a cylinder block with half-a-dozen liners of different composition and arrive at some definite conclusions, providing always the engine gives a commercially-low oil consumption.

The mention of lubrication brings to mind the crying need for bearing-metal alloys to meet the exceedingly high duty performed in motor-omnibus- and aero-engines. The Babbit or tin-base bearing metals are now right up against the duty imposed upon them. Oil-film temperatures in modern bearings are getting into the region of 300 to 350 deg. F., *i.e.*, the "mushy" point of the white metal, at which its compressive strength has practically vanished.

Plain phosphor-bronze is useless in combination with an unhardened crankshaft, due to its non-plastic nature, so some alloy is required of an intermediate nature. Such alloys are being successfully made and used in the U.S.A., but so far as the author is aware there is no English equivalent. The lack of a bearing alloy of the nature indicated is preventing the realisation of about 20 per cent. of the power capable of being developed by motor-omnibus engines, and is responsible for a large part of the cost of upkeep of existing engines, in none of which have bearings anything like the life they should have.

Another item of interest now, and possibly of greater interest in the near future, is that of cast-iron alloys to resist pressures in the order of 1,000 lbs. per sq. in. (*i.e.*, the explosion pressure of a high-speed Diesel engine) without necessitating any considerable increase in cylinder-wall thickness. The problem of a high-expansion cylinder iron for use in conjunction with aluminium pistons has already been tackled, but so far as the author's information goes the alloy is scarcely suitable for a cylinder-block casting and is only used for inserted liners. Its successful solution, however, is of the greatest importance to the development of the high-speed petrol engine. Similarly, alloys suitable for resisting the wear of modern brake-lining fabrics are a crying need of motor-omnibus engineers, and, apparently, are easier to be found in one or other varieties of cast iron than in either cast or forged steel. The items mentioned above come to mind in reviewing a very few of the engineering problems facing most motor manufacturers.

Whilst the author would not suggest what may or may not be subject matter for individual or joint research, he would remark on one difficulty he has observed in research work generally. This is that the research worker is usually so employed because of academic distinctions, and is far too apt to lose sight of the essential practical end sought in the possibly greater scientific interest of secondary aspects of the matter under investigation.

### Defective Research Work.

Further, there is the ever-present difficulty of stating the desired end in clear and unmistakable terms. A vast amount of research work is abortive through lack of informed criticism in the initial stages, and a little time spent in obtaining the opinions of interested and disinterested outsiders would give many research programmes a sense of direction which was very different from that suggested by their sponsors. In research work it is all too easy for the investigator to find what he is seeking and to develop means for stopping the flow at the spigot whilst the precious fluid is running out at the bung. There seems to be a great tendency on the part of metallurgists to think in terms of the test-piece only, and to bestow merit in accordance with the behaviour of a metal under the conditions of physical testing prescribed in times when mechanical design was a matter of application of the methods of the millwright.

### Importance of Tensile Strength Exaggerated.

Thus, there is a nervousness about the use of straightforward cast iron because of its relatively low test-piece properties, regardless of the duty it is called upon to perform. Few metallurgists, and, for that matter, few engineers, would have established cast iron as a suitable material for motor-car engine cylinders involving pressures up to 1,000 lbs. per sq. in., if in the infancy of motor engineering high-strength ductile materials had been equally available. Similarly, few things are more interesting than that a piston made of cast aluminium-alloy, weighing about 1¼ lbs., with a low-tensile strength and no elongation, can transmit 10 h.p. in mediocre everyday practice and withstand indefinitely a pressure amounting to 1½ tons applied 50 to 75 times per sec. Castings have, therefore, by sheer inevitability of use, proved themselves as a very reliable method of fabrication.

### Stiffness a Criterion.

The broad reason underlying all this is that engineering structures have in very many cases long since passed the stage at which the tensile strength or elongation of a material cuts much ice except where pure tension is concerned, as in boilers and wire ropes. What has happened during the last thirty years with increasing acceleration is the speeding-up of mechanism generally and a gradual realisation that the criterion of suitability of a structure such as a crankcase or a cylinder, or for that matter any part, is its stiffness rather than its strength. The old millwright's maxim that "If it wants to wobble let it wobble" is nowadays consigned to the discard. Thus stiffness and surface qualities are beginning to assume their true importance in the minds of engineers, and maybe in those of metallurgists.

### A Bend as Bad as a Break.

Even now engineering students are still educated in terms of the modulus of a section rather than its moment in inertia, *i.e.*, in terms of what will break it rather than what will bend it. Now, as the moment of inertia of any section subjected to bending is proportional to the fourth power of any linear dimension, and the modulus is proportional to the cube of any linear dimension, one finds that stiffness and low stresses go hand in hand and that, in general, any part which is stiff enough is more than amply strong and can. therefore, be made of materials which from the test-piece viewpoint may seem utterly inadequate.

### Treacherous Forgings.

The result is that in many parts castings fulfil entirely the required conditions as to strength and reliability, and confer wearing qualities combined with cheapness and convenience unattainable in any other way. There is thus no reason to fear that castings may be displaced by forgings because of any superior physical qualities of the latter. In a long experience of the motor industry the author has seen far more failures of forgings than of castings. It is only recently that it is being recognised that forged steel is apt to be like wood, very weak in cross-grain direction, so much so that a series of tests on alloy steels of repute show that the cross impact test is only about 10 to 15 per cent. of the longitudinal impact test. In general, the worst is known about a casting early on; a forging may deceive for years. This reference to forgings is intended to comfort those of the weaker brethren who may feel that the motor industry is so idealistic as not to realise the many and legitimate claims of an honest casting.

### Lessons from American Developments.

In the author's opinion the applications of ferrous and non-ferrous castings to motor-car construction are so enormous as to merit the specialisation essential to the successful development of even one application. It is, however, necessary to specialise. One of the many lessons learnt by the author during nearly eight years in the U.S.A. spent in very close touch with the automobile engineering and foundry business, was that the general foundry had very little place in the firmament. On the other hand, it is not to be thought for one moment that the methods of the U.S.A. have any monopoly of efficiency. Given a demand for, say, 20,000 pistons per day at remunerative prices, efficiency naturally follows, and what is more, a whole lot of system so-called which is not by any means efficient. In these days, when the Press is full of national disparagement, the author feels it is the duty of those who have experience of other countries to contribute such knowledge as they may have to enable us to see ourselves as we are, especially as in this case it has a bearing upon the points being discussed.

### Cheap Cars and High Cost of Living.

In the U.S.A. the motor car is the only article of public consumption which is cheap, relatively and absolutely. Clothes, rent, fuel, hotel accommodation, restaurant meals, are roughly double for the same quality. Whilst the industrial worker has a definitely larger margin for saving than in England, this margin and far more disappears in the hire-purchase of wireless sets, fur coats, automobiles, vacuum cleaners, etc., etc., so that when the pinch comes, as during the last year, the American workman and his family are definitely worse off than the workman in England. When one goes higher up the scale to the minor or even major executive, a far larger salary is required to enjoy the same amenities of social life than in this country.

### Repercussion on Exports.

A very interesting and important fact emerges from the cheapness of the motor car, and the overwhelming importance of the motor industry. In large-scale mass production, such as is applied to motor cars, the hourly rate of wages means little, whilst the machine and organisation mean a great deal. Hence, high hourly rates (roughly 2s. 6d. to 3s. 6d. per hour) are paid in the motor industry, and have perforce to be paid by other industries in which

there may be no possibility of mass production, such as the machine-tool, patternmaking and heavy-engineering trades generally. From the point of view of world competition these trades in the U.S.A. are, therefore, heavily handicapped. Nor are these high-wage rates compensated for by any extra efficiency of the labour employed. In actual fact the time taken in making a pattern or a die or any individual piece is very considerably greater in the U.S.A., which is reflected in the cost for a pattern or a die or any special piece of work being about four times what it is here.

### Overtime on Labour-Saving Devices.

The author may seem inconsistent in advocating intense specialisation to the British foundry trade, if it brings the appalling social and economic consequences now so painfully evident in the U.S.A. It is, however, necessary to consider any system of working which promotes economy and improvement of product, and there is not the slightest need for this country, in so doing, to become what America was three years ago—a nation working overtime making labour-saving devices. The basic education, training, skill and natural intelligence of the British worker, either in the shops or in the office, are very definitely higher than in the U.S.A., and he is much more likely to offset the unemployment consequential upon intensive economic production by a steadily increased leisure than by alternate overtime and starvation.

The motor industry is already rapidly developing upon mass-production lines, and forms, undoubtedly, the most efficient link in the manufacturing processes between the raw material and the finished motor car. Whilst there are a few motor manufacturers whose methods do not encourage much enterprise in the foundry trade, the output from these is insignificant and, commercially speaking, the motor trade is in the hands of a relatively small number of makers with large outputs.

This means that this country will follow and improve upon the American method, and develop outputs which will be much bigger than now in order to supply domestic and Dominion demands. In brief, the British motor industry has passed through its parish pump and local government stages and is about to become a dominating factor in British Imperial trade.

The author, therefore, returns to the specialisation of foundries on certain motor-car parts as being the logical road to cost reduction in respect of that important section of raw material represented by ferrous and non-ferrous castings. He suggests that it can do the foundry industry no harm to keep a watchful eye upon these developments and, consistent with good business, to anticipate the motor makers' requirements.

### Current Industrial Position.

Basically, quantity is the biggest factor in cost reduction, but the problems of cost reduction are in themselves subtle and complicated and need some thought ahead of actual requirements. Dismiss the idea that everything is going to the dogs because of a couple of years in which trade is 25 per cent. less than a couple of years ago, but still leaving a community enjoying more real wealth in the shape of goods and service than ever before.

The momentum of prosperity always projects itself across the abyss of trade depression and reveals hitherto unsuspected opportunities for progress on the other side. It is no longer possible, if it ever was, to conduct related industries in water-tight compartments. The problems before the engineer and the foundryman interlock and overlap to the extent that lines of demarcation are impossible, and in these circumstances the freest and frankest interchanges of experience and opinion between the interested trades is not only a counsel of commonsense but of sound business.

## Recent Developments in Cast Iron and Foundry Practice in Great Britain.

(*Concluded from page* 24.)

tories on the same iron. Where such differences are due to the heterogeneity of the material itself, they cannot be overcome, and, in fact, they are a valuable index to the extent of the heterogeneity. But where they arise from differences in the laboratory methods of analysis, remedial differences in modes of sampling, etc., they form a source of constant friction in the trade between the buyer and seller and the Association, in addition to the report mentioned above on methods of testing moulding sands, has issued recommended methods of sampling and analysis, for pig-iron, white and grey iron and cast steel, and also including coke, coal dust, blackings, plumbagos, etc. The sands report covers sands and refractories. These two reports, therefore, form a useful basis for internal standardisation in the industry, and the demand for them is indicated by the fact that at present they are both out of print. New editions will be available during the next few months. The Association, of course, is greatly concerned with standardisation of test-pieces, test procedure and methods, and assists where necessary in the consideration of specifications issued by the British Engineering Standards Association.

### Conclusion.

The manner in which the Association is organised is such that the whole of the staff works as a team, and, whoever is charged with the responsibility of presenting a particular report or Paper, every member of the staff shares in the work described to a greater or lesser degree. The mode of organisation permits a very high degree of specialisation in its component parts. The Association also works in very close contact with other bodies who are concerned with research work which may interest the industry, particularly with the Iron and Steel Industrial Research Council recently formed by the National Federation of Iron and Steel Manufacturers, and which conducts important investigations into metallurgical coke, and with the other research associations.

The work would also not be possible without the very great willingness invariably shown by members to co-operate in providing facilities in experiment. Also, the Association is greatly indebted to firms engaged in the supply of foundry equipment and materials for the readiness with which they co-operate to the same end. The Council greatly values this co-operation, as it believes that the interests of suppliers of foundry materials and equipment and of makers of castings are identical, in that both need castings of low production cost and high quality, able to maintain the status of the industry and compete with the alternatives which are available.

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## Silicon as an Alloying Element.

MR. J. ARNOTT'S Paper* on this subject, presented at the Birmingham Convention of the Institute of British Foundrymen, was generally commended during the discussion as a succinct statement of the position which the range of silicon alloys occupies to-day.

### Two Advantages of Copper-Silicon Alloys.

MR. H. C. DEWS said that the author was to be thanked for his Paper, for the valuable information it contained concerning an alloy which had received a good deal of public discussion recently, and also because it provided an authoritative account from one who knew so much about silicon as an alloying element. Silicon bronze had recently received a good deal of commercial publicity, and it had been claimed that these silicon alloys were superior in most respects to gun-metal. The author, however, very wisely did not claim any great superiority for the copper-silicon alloys over Admiralty gun-metal. As far as the speaker could understand from the Paper, the physical properties of the two alloys were very similar, and the only point in which superiority in mechanical properties was claimed in the Paper for the copper-silicon alloys was that they were somewhat harder, the Brinell hardness number being a little over 100 as compared with about 80 for Admiralty gun-metal. That was a definite advantage for many purposes. Another advantage which the author pointed out—and with which he entirely agreed—was the possibility of getting a nicer skin with these alloys than with Admiralty gun-metal. The Paper stated: "Dressing is easy and the machine shops find that the clean skin is light on tools." With that he quite agreed.

### High Shrinkage Detrimental.

The Paper, however, pointed out that a serious drawback with these alloys was that the shrinkage was very high. That was entirely contradictory to the data previously published about them, which had been to the effect that the shrinkage was low. Personally, however, he agreed that the shrinkage was high, and if one tried to make castings such as are made with Admiralty gun-metal of these alloys, with the same runners and risers, they would be hopeless failures. In the table of physical properties, the author gave the elastic limit as 5 tons per sq. in. for copper-silicon. That was a rather unusual feature for non-ferrous alloys of this description, and he welcomed the figure particularly because he believed that reliable figures for the elastic limit of Admiralty gun-metal had never yet been published in spite of the fact that this alloy had been used for so many years and for so many purposes.

With regard to nickel-silicon alloys, he would like to know if the figures for the Brinell hardness related to the "as-cast" material, because that material was very susceptible to heat-treatment and variations in hardness resulted therefrom.

There was one rather sweeping statement in the Paper, just before the conclusions, where it was stated "They probably represent the highest combination of strength, hardness and corrosion resistance available commercially to-day in the whole range of non-ferrous castings." Personally he could not agree with that.

The AUTHOR, in reply, said that perhaps he ought to qualify the Paper by saying that when tin was cheap, as it is to-day, the price advantage of any of the silicon alloys largely disappeared, but if tin ever returned to a price of £200 or £300 per ton, as some people would wish, then, of course, the silicon alloy had a very big advantage. To-day, however, tin was down to about £100, and then the price advantage disappeared very largely. He was in-

(*Concluded on page* 28.)

* FOUNDRY TRADE JOURNAL, June 11, p. 397, vol. 44.

# The Making of a Carding-Engine Cylinder.*

By B. Simpson.

The making of a carding-engine cylinder in the ordinary sense does not include any difficult moulding or coremaking, but when a certain type of casting is demanded in large numbers, ways and means have to be devised in order to operate economically. Thus one cannot afford to utilise old-fashioned methods of moulding, as is possible for one-off jobs. Therefore a plant destined to shorten and simplify the method of moulding to a minimum is essential.

The plant for this particular casting includes standard metal patterns and boxes, permanently-constructed pits for receiving the boxes, and—most important of all—a collapsible core barrel.

The shape of the casting is just a simple and ordinary cylinder, having internal flanges both at the top and bottom. The inside of the cylinder is ribbed with broad, shallow ribs about $\frac{3}{8}$ in. thick. The size of the castings varies from about 4 ft. 6 in. to 6 ft. in length and from 20 in. to somewhere about 45 in. in diameter; the thickness also varies about $\frac{3}{8}$ to $\frac{1}{2}$ in.

The boxes used are essentially in two parts. The top portion, which contains all the casting, and the lower portion, which is shaped for the seating in order to receive the pattern and core respectively. The box is perforated to facilitate venting and drying. The top of the box is bell-shaped in order to form the runner head, as shown in Fig. 1. The bottom box is secured to the top portion by means of clamps on the flanges of the box. Initially, the box is placed in position by resting on brackets which are cast on the box and supported by girders. It is levelled by wedges placed between the brackets and girders. The pattern is next placed in the box, where it finds its position in the seating provided. The space between the pattern and box is about $1\frac{1}{4}$ in., and the mould is rammed up with rammers about $\frac{3}{4}$ in. thick. The moulder keeps to the outside all the time and so ensures that the mould density is uniform.

The patterns are usually shorter than the moulds, so that they have to be lifted up gradually and held in position by the crane. The reason for this is that one is able to hoist up the patterns well clear of the box and other obstacles. Considerable height is thus saved. Having rammed up the mould, the runner is made by scooping out to the shape of the shell. The pattern is withdrawn, the mould is blacked with wet blacking and dried by a fire suspended by a bar across the box.

### Core Making.

The core is made on a collapsible core barrel; that is, one in which all its component parts come asunder. The barrel is composed of nine segments; this includes six segments which form the circumference of the barrel, two barrel ends, and one spindle on which it rotates in journals of the trestles. The barrel-ends are not the same size, the one corresponding to the top of the core being a little larger on account of the bearing, which is made the same size as the mould. Three of the circumferential segments are fast to the spindle by means of a hinged arrangement supported by brackets as shown in Fig. 2. These hinges allow them to be swung closer together and so liberate them from the casting. The other three are loose. Each segment has an eye-bolt at the top for lifting purposes in assembling the barrel together. The seating barrel end is placed over a small square hole about 2 ft. 6 in. square and 1 in. deep. This is to receive the spindle and also to fasten the spindle to the end of the barrel by cotters. The rim of the barrel-ends project upwards to about $\frac{1}{2}$ in. so as to hold the segments in position into the recess provided for them, as shown in Fig. 3.

As the spindle is guided into the boss of the barrel-end, the segments swing out on their hinges to the outside. The job is then made secure by cottering together the spindle and barrel-end. The loose segments are next put into position, each loose segment is introduced by the crane, and when it reaches the bottom end the chain is taken off and it is replaced by a smaller chain having a rubber ring in the

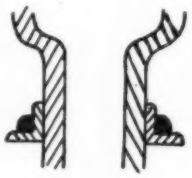

Fig. 1.

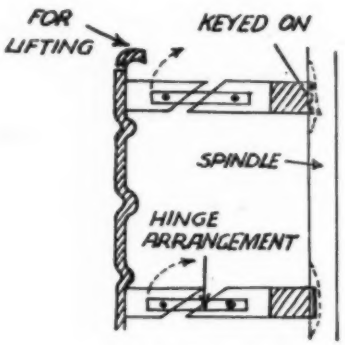


Fig. 2.

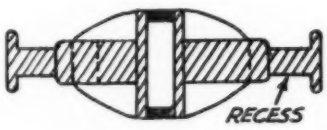


Fig. 3.

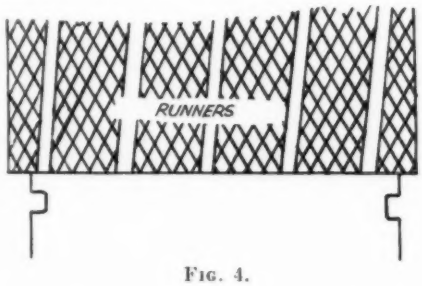


Fig. 4.

centre. One of the hooks goes round the spindle whilst the other is attached to the segment. This rubber stretches and so keeps the loose segments in position whilst the top end of the barrel is placed on. Otherwise it would need three men to hold the segments while putting the barrel-end on. After cottering up it is placed on the trestles, but before starting to make the core all segments of the barrel are made secure by driving wedges between the rim and the core barrel. Three of the segments usually have facings on, and the barrel is normally wedged until these touch. This wedging prevents the barrel from springing and so does not offer any difficulty when putting loam on. The making of the core is then of the ordinary procedure, being struck up in loam. When dried it is turned to proper size. A point of interest is that the shape of the seating is not exactly conical, but it is slightly eccentric. The reason for this is that it produces a fin which leaves the metal in a soft condition, and also that it is much easier to keep the seating uniform than if a true cone shape was made. The barrel is perforated with conical holes, which facilitates venting and strengthens the plates. The average thickness of the barrel is about 1 in.

The advantage of using the collapsible barrel is that the casting can be stripped from the barrel the moment it is set, and it enables the moulder to strike up the core without any loss of time. Moreover, it allows the casting to contract freely and cool uniformly. Owing to the shape of the core barrel being of the same contour as the core much loam is saved, *and therefore does not require so much drying.*

The runners are cut in the bearing of the core, all the way round. They are not vertical, but are inclined as shown in Fig. 4. By this method the mould is filled much more quickly, as it flows in a circular fashion.

* A Paper read before the Lancashire Junior Section of the Institute of British Foundrymen, Mr. H. V. Grundy presiding.

## Silicon as an Alloying Element.

(*Concluded from page 27.*)

terested in what had been said with regard to the elastic limit. There were very few people who carried out extensometer tests, but he himself had had much to do with them, and it was a distinct advantage, especially on highly-stressed parts, definitely to know the elastic limit. Mr. Dews did not complete his criticisms by saying what was the best combination. He should certainly like to know what horse Mr. Dews backed!

### Modified Alloys.

A Speaker asked the author whether in his Paper he referred to modified alloys or the ordinary alloy of silicon and aluminium.

The Author said that opened up a very big subject. He did not like the word "modification"; it had rather been overdone. The original data given concerning straight aluminium-silicon alloys were not reliable because the silicon available at that time was not pure, and much of the brittleness of the early alloys was due to that. A great deal that had been claimed for modification could be obtained to-day without processes coming under the name of "modification" because the silicon to-day was much purer.

The Chairman (Mr. Victor Stobie) asked if the author could give any idea of the limits of proportionality of these silicon alloys.

The Author replied that in a material such as this, the limit of proportionality is very close to the elastic limit. There were differences between the two, chiefly in forged and heat-treated material, but generally, in ordinary cast material, it could be taken that the figures for the two things were coincident, for commercial purposes.

### Deoxidising Effect of Silicon.

Mr. Laverton, referring to the statement in the Paper that in the case of copper-silicon alloys the copper is deoxidised with phosphorus before adding the silicon, asked whether the silicon had any further deoxidising effect, as when added to ferrous metals.

The Author said that silicon certainly had a deoxidising effect, but apparently its range was very narrow. It was not so positive as phosphorus, and it also had the disadvantage that its oxide is a solid, whereas, when phosphorus was used as a deoxidising agent, the product of deoxidation is phosphoric acid, and it did not mix in with the alloy. Therefore it was best to deoxidise with phosphorus before adding any silicon.

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| SULPHUR.. .. | 0.07 | 0.05 | 0.03 | TRACES |
| PHOSPHORUS .. | 1.45 | 0.90 | 0.80 | 0.25 |
| MANGANESE .. | 2.00 | 1.00 | 1.00 | 78.00 |
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## Trade Talk.

Messrs. August's Muffle Furnaces, Limited, of Thorn Tree Works, Halifax, have received an important order from a well-known gear-manufacturing firm near Paris for mould- and core-drying equipment.

Messrs. Scott & Sons, Bowling, have launched the "Yewarch," a screw steamer built to the order of John Stewart & Company, Limited, Glasgow, for coasting trade. Triple-expansion machinery is being installed by the builders

Three Diesel-electric trains will shortly be tried out on three of the British railway systems. They are being built at the Newcastle works of Messrs. Sir W. G. Armstrong, Whitworth & Company (Engineers), Limited.

Messrs. Vickers-Armstrongs, Limited, John I. Thornycroft & Company, Limited, and R. & W. Hawthorn, Leslie & Company, Limited, have jointly signed a contract with the Portuguese Government for the building of two 1,000-ton sloops in England.

Scott's Shipbuilding & Engineering Company, Limited, have launched from their Cartsburn Yard the oil-tanker "Eclipse," built for the Standard Transportation Company, New York. The gross tonnage of the vessel is 9,800, with a deadweight carrying capacity of 13,800 tons.

Negotiations between the employers in the steel-melting and steel-manipulating industries of Sheffield and the trade unions, with regard to the men employed on the Sheffield shift system and in receipt of the consolidated shift war bonus, have resulted in an agreement being arrived at for a reduction of 10d. per shift, or 5s. a week, the reduction to be made in two stages.

Mining & Industrial Equipment, Limited, 11, Southampton Row, London, W.C.1, report that new orders have been received for the following equipment: For England, a Hardinge ball mill, a Hummer electric screen, three Rovac filters and two Raymond pulverisers; for South America, three Hardinge ball mills, and for South Africa, an Impax pulveriser.

The Board of Trade announces that new Orders-in-Council have been made under Section 2 of the Merchandise Marks Act, 1926, requiring (1) imported air or gas compressors or exhausters, and pneumatic tools or appliances, and (2) electricity meters and certain parts, to bear an indication of origin on importation or on sale or exposure for sale in the United Kingdom. Both Orders will come into force on September 29 next.

At a special meeting of Crucible Steel & Castings, Limited, a resolution was passed that the company go into voluntary liquidation, and that Mr. J. H. Freeborough, of Figtree Lane, Sheffield, be appointed liquidator. At a subsequent meeting of the creditors the resolution was confirmed, and the liquidator said that, owing to the voluntary act of the directors in taking over the liability to the bank, the claims of the shareholders would be practically met in full.

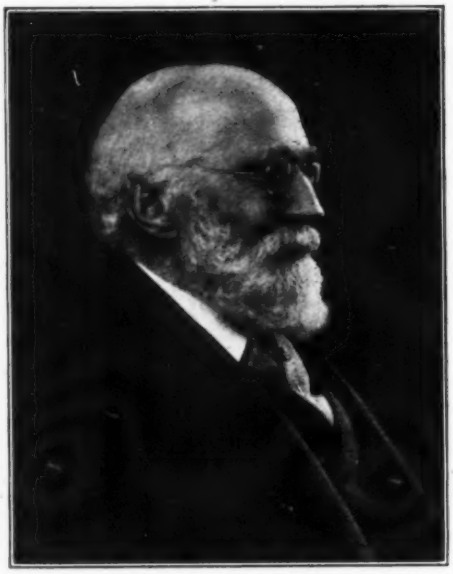
According to a Paris correspondent, owing to the heavy decline in inland sales, a scheme is under consideration to form a Union des Aciéries for France on the model of the German Stahlwerks Verband. The correspondent, however, thinks that the formation of such a Steelworks Union will meet with many difficulties, and that its realisation will depend on the formulation of agreements with the Belgian and Saar iron and steel industry for the mutual protection of home markets.

Messrs. Harland & Wolff, Limited, Govan, have launched the "Conch," one of a group of oil-tankers which is being added to the fleet of the Anglo-Saxon Petroleum Company. The "Conch" has been built to Lloyd's 100 A1 class, for the carriage of about 11,500 tons of petroleum in bulk. The firm has received an order from the Wallasey Town Council to build a ferry steamer for Wallasey's Mersey fleet. The vessel will have accommodation for 2,500 and a speed of 12 knots.

The Provost of Coatbridge has received a letter from the manager and secretary of the Coatbridge & Airdrie Electric Supply Company, referring to the resolution passed at a special meeting of the Town Council on June 8 regarding the continuance of negotiations with a local company for the future supply of electricity, and informing him that it had been decided to place a large order for piping equipment with a manufacturer in Coatbridge. The order has been placed by the Coatbridge company's associated company, the County of London Electric Supply Company, with Messrs. Stewarts & Lloyds, Limited, and is valued at £100,000.

## The Late Sir Hugh Bell.

The death of Sir Thomas Hugh Bell, at the mature age of 87, removes one whose name was a household word in the Cleveland district, and whose industrial and public activities had a world-wide reputation. The elder son of Sir Isaac Lowthian Bell, Bt., he was sent in his early days to Merchiston Castle School, Edinburgh, going to Paris at the age of 15, where for twelve months he studied chemistry at the Sorbonne under St. Clair Deville, and later continued his studies at Göttingen. At the age of eighteen Hugh Bell entered the family business, and later directed the Port Clarence Works, which will always be associated with his father, then Isaac Lowthian Bell, and the prominent part which he played in the development of the Cleveland iron industry. In 1872 the business was converted into a limited company, and in 1899 Bell Brothers, Limited, was floated as a public company in conjunction with Dorman, Long & Company, Limited, and steelworks were



The Late Sir Hugh Bell.

erected at Port Clarence. On the formation of Bell Brothers, Limited, Hugh Bell became a director, and when the public company was formed in 1899 he was appointed managing director, and subsequently chairman on the death of his father. He succeeded to the baronetcy in 1904. In 1923, Dorman, Long & Company, Limited, by a reorganisation of their subsidiary companies, took over the entire properties and plant of Bell Brothers, Limited, Sir B. Samuelson & Company, Limited, and the Carlton Iron Company, Limited, Sir Hugh Bell becoming a director. He was also chairman of Horden Collieries, Limited, and was interested in a number of other industrial undertakings.

Sir Hugh Bell was a Past-President of the Iron and Steel Institute, and was presented with the Bessemer Medal in 1926. He was an ardent Free Trader and steadfastly maintained his views in face of the recently growing tendency throughout the steel industry in favour of Protection. He was recently made hon. D.C.L. of Oxford, was a member of the Senate of the University of Durham, hon. LL.D. of Leeds and Sheffield, and a J.P. for the County of Durham.

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Several prominent foundry concerns are exhibiting at the Royal Show, which opened last Tuesday, at Warwick. They include agricultural and general engineers; Petters, Limited, Listers & Sidney Flavel & Company, Limited, all of whom have favoured us with descriptions of their exhibits.

## The Importation of Light Castings.

A fairly serious situation was revealed by Mr. W. Graham, the President of the Board of Trade, in a written answer to Mr. Dukes, who had asked for the import figures to the country for 1928, 1929 and 1930 for stoves, grates, sanitary cisterns, baths and other sanitary cast-iron goods, and cooking and washing boilers. The figures, detailed below, show the loss which just one small section of the British foundry suffers from Continental competition.

| Description. | 1928. | | 1929. | | 1930*. | |
|---|---|---|---|---|---|---|
| | Quantity. | Declared Value. | Quantity. | Declared Value. | Quantity. | Declared Value. |
| Stoves, grates and ranges for domestic cooking and heating: | Tons. | £ | Tons. | £ | Tons. | £ |
| For coal and other solid fuel .. | 958 | 47,470 | 812 | 50,026 | 847 | 48,873 |
| For gas .. | 187 | 16,301 | 154 | 11,365 | 98 | 8,074 |
| For liquid fuel .. | 1,799 | 246,236 | 1,874 | 275,269 | 1,490 | 217,357 |
| Sanitary cisterns (flushing tanks) .. | 77 | 1,152 | 132 | 2,481 | 20 | 361 |
| Baths (porcelain enamelled or other finish) .. | 8,272 | 221,830 | 6,794 | 190,581 | 7,530 | 208,187 |
| Other sanitary cast-iron goods, enamelled or not (such as sinks, basins, lavatories, closets, etc.) | 255 | 16,521 | 228 | 12,346 | 191 | 9,078 |
| Cooking and washing boilers .. | 94 | 2,869 | 36 | 1,472 | 181 | 5,477 |

* The figures for 1930 are provisional.

## Personal.

Mr. William Lindsay, of Dunaskin, Ayrshire, who has served for the past 51 years with the Dalmellington Iron Company, Limited, has retired.

Since his return from a tour of the British Empire, Major James Caldwell, M.Inst.C.E., M.I.E.E., has accepted the invitation of the Quasi-Arc Company, Limited, to join their research committee and assist in extending the application of electric welding to welded-steel construction.

Three industrial veterans well known in the Lanarkshire steel trade retired at the end of June under the age limit in Colville's Clydebridge Steel Works. They are Mr. John R. Robertson, chief clerk; Mr. Matthew Maxwell, pay clerk, and Mr. George Hinshelwood, mill foreman. Their combined services at Clydebridge exceed 112 years.

In recognition of valuable services rendered by Mr. Joseph Brass to the Glasgow and West of Scotland Association of Foremen Engineers and Draughtsmen, members of the Association have presented him with their diploma on the occasion of his retirement from business. Mr. Brass served his apprenticeship with Barclay, Curle & Company, Limited, Glasgow, in 1882. He later became foreman engineer and ultimately succeeded to the position of works manager, which he held until his retirement. He was responsible for the erection of the first Burmeister-type Diesel engine which was built in this country by Messrs. Barclay, Curle.

### Wills.

Highton, R. E., managing director of the Workington Iron & Steel Company... £33,029

## Obituary.

We regret to announce the death of Dr. Franz Bauwens, for many years the director of the German Steel Foundry Owners' Federation.

Mr. John Hemming died recently at his home in Walsall, in his 70th year. Mr. Hemming was formerly managing director of Messrs. F. H. Lloyd & Company, Limited, James Bridge Steelworks, Wednesbury, retiring from active work a few years ago.

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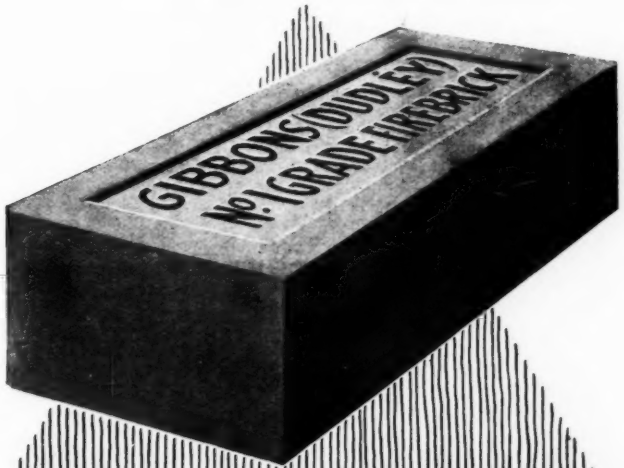


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Street's

# Iron and Steel Markets.

## Pig-Iron.

**MIDDLESBROUGH.**—Business is extremely dull in the Cleveland area. Even the smallest orders are difficult to obtain. The ironmasters have again reaffirmed the prices which have prevailed since the beginning of the year, and have insisted once more that no reductions need be expected. The makers believe that lower prices would not materially increase the demand while industry is so depressed, and it is certain that only a drastic wielding of the axe would bring Cleveland prices down to the level of the prices quoted abroad. The position, therefore, is that Cleveland quotations are unaltered, and they are so far above prices quoted elsewhere that external markets have been almost wholly lost, and Cleveland is importing by rail and by sea more iron than she is exporting. Moreover, those consumers who still prefer Cleveland iron are buying in truck loads where they used to buy hundreds of tons, and usually they stipulate for prompt delivery. No big contracts are being placed, and it now seems as if more blast furnaces will have to be laid idle failing a drastic change in the market, although on the whole of the North-East Coast there are now only 22 furnaces at work, seven of which are producing Cleveland iron and seven hematite. The fixed Cleveland iron prices, except to Scottish destinations, are:—No. 1 foundry quality, 61s.; No. 3 G.M.B., 58s. 6d.; No. 4 foundry, 57s. 6d.; No. 4 forge, 57s. per ton.

Hematite trade in the East Coast area is dull. The aggregate tonnage is negligible and works are chiefly kept going on contracts already on the books. Although numerous prompt orders are circulating, there is a marked disinclination on the part of consumers to enter into any more forward commitments, and foreign orders are secured with increasing difficulty owing to the growing severity of foreign competition. Makers are insisting that further price cuts are out of the question, and this week they adhered to quotations of 62s. 6d. per ton for mixed numbers and 63s. for No. 1 quality. Bessemer mixed numbers on the North-West Coast are still nominally quoted at 66s.

**LANCASHIRE.**—Trade is perhaps slightly better in this district. An increase in the number of orders on the books of textile machinery manufacturers has been reported, and the better movement of pig-iron has been largely due to this, and also to the fact that certain speciality foundries have fair order books. With regard to prices in this section, there has been very little further change on balance to report. For delivery to consumers in the Manchester zone, Derbyshire and Staffordshire descriptions of No. 3 are quoted at 67s. per ton, with North-East Coast iron also at 67s. The price of Northamptonshire foundry is 65s. 6d. and Derbyshire forge 62s. Scottish foundry brands are quoted at about 87s. 6d., with West Coast hematite iron at 80s. 6d.

**MIDLANDS.**—Trade is quiet. Foundry pig-iron is in limited demand, and most of the ironfounders are in need of more work. For delivery to Birmingham and Black Country stations the furnaces still quote 62s. 6d. for Northants No. 3 and 66s. for Derbyshire, North Staffordshire and Lincolnshire No. 3.

**SCOTLAND.**—The holidays have reduced business considerably, and an improvement in market conditions is not expected for some time. Scottish pig-iron makers are quoting as a fixed minimum price 71s. per ton for No. 3 foundry, f.o.t. furnaces, with a minimum of 2s. 6d. per ton extra for No. 1. The price of Continental No. 3 is 52s., f.o.t. Grangemouth. Middlesbrough No. 3 is at 58s. 6d.

## Finished Iron.

The finished-iron market remains in a depressed condition. Orders are invariably small, and the mills are only working spasmodically. With regard to crown iron there is no indication of any improvement having set in, and all the mills continue to be very short of work, with no possibility of being able to keep their mills in regular operation. Quotations for crown bars still fluctuate widely, anything from £9 5s. to £10 being quoted, with nut and bolt iron at £8 10s. to £8 12s. 6d. Staffordshire marked bars are maintained at £12. For common nut and bolt work the Belgian product is being purchased, the present price delivered to Black Country works being between £4 12s. 6d. and £4 15s.

## Steel.

The demand for finished steel is slack, pending the review of prices to be made by the associated steelmakers at their meeting in the middle of this month. The small steel-bar market remains quiet. Galvanised steel sheets have a slightly improved demand, mainly due to the low prices quoted, but the position is far from good. There is little demand for semi-finished steel, although the higher prices of Continental semi-finished steel are maintained. Generally, prices of Continental semis are about 1s. 6d. higher on the week. The home market for semi-finished steel has undergone no change, the makers maintaining their prices at the lower levels recently recorded.

## Scrap.

Industry generally is in a depressed condition, and works will buy only to cover their immediate needs. Ordinary-quality cast-iron scrap is now down to 42s. 6d., with good machinery quality at 44s. Conditions are similar in the Midlands, where new business is difficult to secure. Good heavy machinery cast-iron scrap in cupola sizes is offered at 47s. 6d., with light cast iron at 37s. 6d. The Scottish market is also quiet. Orders are very scarce. First-class machinery metal, in pieces not exceeding 1 cwt., is quoted at 47s. 6d. to 48s. 6d., while ordinary cast-iron scrap to the same specification is at 42s. 6d. to 43s. 6d. The above prices are all delivered consumers' works.

## Metals.

**Copper.**—The present situation on the copper market is rather obscure. The higher prices are maintained, and the tone of the market is more satisfactory, but, at the same time, it is feared that the trade situation in Europe has not materially altered, while the industrial depression in the United States has not yet been checked. In that case permanent stability cannot be expected. Rumours of greater restriction have been circulating, but have been denied.

Closing quotations :—

*Cash.*—Thursday, £37 17s. 6d. to £38; Friday, £36 18s. 9d. to £37 1s. 3d.; Monday, £37 1s. 3d. to £37 3s. 9d.; Tuesday, £36 10s. to £36 12s. 6d.; Wednesday, £35 to £35 2s. 6d.

*Three Months.*—Thursday, £38 10s. to £38 12s. 6d.; Friday, £37 11s. 3d. to £37 12s. 6d.; Monday, £37 15s. to £37 16s. 3d.; Tuesday, £37 2s. 6d. to £37 5s.; Wednesday, £35 12s. 6d. to £35 15s.

**Tin.**—After the publication of the June statistics, interest is now directed towards the possible results disclosed by this month's figures. It is hoped that the Hoover proposal, if it is adopted, will have a beneficial influence on world consumption, but, obviously, some time must elapse before the full effect can be seen. The June statistics showed an increase in the visible supply of around 470 tons, the carry-over in the Straits amounting to 7,202 tons, against 6,865 tons a month earlier. The Straits' smelter output in July is estimated at 6,500 tons, and the shipments also at 6,500 tons.

Official closing prices :—

*Cash.*—Thursday, £117 to £117 2s. 6d.; Friday, £117 2s. 6d. to £117 5s.; Monday, £119 to £119 2s. 6d.; Tuesday, £117 12s. 6d. to £117 15s.; Wednesday, £113 5s. to £113 7s. 6d.

*Three Months.*—Thursday, £118 17s. 6d. to £119; Friday, £118 17s. 6d. to £119; Monday, £120 15s. to £120 17s. 6d.; Tuesday, £119 10s. to £119 12s. 6d.; Wednesday, £115 to £115 2s. 6d.

**Spelter.**—The market has now a rather uncertain aspect. Business with consumers is not so active as it has recently been, although there are still a fair number of inquiries on the market.

Daily fluctuations :—

*Ordinary.*—Thursday, £12 18s. 9d.; Friday, £13 3s. 9d.; Monday, £12 17s. 6d.; Tuesday, £13 7s. 6d.; Wednesday, £12 2s. 6d.

**Lead.**—Sentiment still controls the price movements, causing narrow fluctuations, but, on the whole, the tone of the lead market is steady, and the outlook more encouraging.

The week's prices have been :—

*Soft Foreign (Prompt).*—Thursday, £13 5s.; Friday, £13 6s. 3d.; Monday, £13 5s.; Tuesday, £13 7s. 6d.; Wednesday, £12 16s. 3d.

## Correspondence.

*[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]*

### Oxygen in Cast Iron.

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—It has been my pleasure to have read a copy of your JOURNAL of May 28, 1931. I feel complimented to think that you found enough of interest in my Paper on "The Effect of Excessive Atmospheric Moisture in Cupola Blast" to publish it. In reading your Editorial dealing with the Paper, it occurred to me that you must have slightly misunderstood my ideas regarding oxygen in cast iron, or, perhaps, the error was mine in not being clear enough in my discussion of that subject. In either case, I feel that perhaps it would be well for me to explain myself a little more clearly.

Referring to my Paper, you will notice that the first time I mention oxygen I state that it is my belief that this element is the constituent in iron that retards the dissociation of cementite into ferrite and graphite (referring, of course, to the particular condition being discussed) and that this oxygen is present "in some form or other." Thus, you see that, at the outset, I recognised that the form in which oxygen exists in cast iron is an open question.

In other parts of the Paper it is true that I speak of oxygen without regard to its form of combination, but it is also true that in other places I used the term "oxygen content." It was my intention, in speaking of oxygen in these different ways, to speak of it as one would of manganese or manganese content of cast iron, never having in mind to intimate that manganese is present in a free and uncombined state.

Therefore, it would appear that the writer of the editorial and myself are quite in agreement on the fact that the oxygen in cast iron is not present in its free state, but rather combined with some other elements; what element, I am not prepared to say.

Quite apparently there has been some misunderstanding, which has led to an apparent difference of opinion.—Yours, etc.,

NEIL A. MOORE.

The Piston Ring Company,
Muskegon, Michigan,
June 16, 1931.

## New Companies.

**J. B. Machine Tool Company, Limited,** Warwick Chambers, Corporation Street, Birmingham. Capital £100.

**British Foundry Units, Limited,** 52, Bedford Row, London, W.C.—Capital £100. Directors: H. S. Taylor and W. G. Antrobus.

**Lowmoor Foundry, Limited,** 15, St. James's Place, London, S.W.—Capital £10,000. Directors: Sir E. R. Debenham, Bt., and E. D. Rowley.

**William Eagles, Limited,** Springfield Works, Springfield Lane, Salford.—Capital £1,000. Brassfounders, etc. Directors: F. S. Hyde and J. Garvie.

**T. Baker & Sons (Compton), Limited,** White Wall Ironworks, Compton, Berks.—Capital £28,000 in £1 shares (12,000 6 per cent. cumulative preference). Ironfounders, etc. Directors: Gladys & D. T. Baker and W. L. Keighley.

# Sterling

## ALL STEEL TUBULAR

# WHEELBARROWS

## ARE IDEAL FOR ALL FOUNDRY PURPOSES.
## THEY POSSESS MANY IMPORTANT ADVANTAGES.

Tray set well forward.
The load is on the Wheel.

Tray Reinforced with Stout Continuous Rod.

Broad Tyred 10-spoke Wheel.

Substantial Nose for forward dumping.

Strong Tubular Handles.

Patent Clip avoids perforating the Handle at point of strain.

Legs strongly braced cannot get shaky.

Pre-lubricated Axle-bearings. Never require oiling.

Legs bent square and fitted with renewable Shoes.

**A Sterling Product designed for hard work and built to last.**
**All parts are standardised and interchangeable for repairs.**
**Capacities from 2½ to 6 cubic feet.**
**Also special barrows for pig iron and coke.**

*Write for Booklet No. W.39.*

**STERLING FOUNDRY SPECIALTIES Limited**
LONDON OFFICE:—13 VICTORIA STREET, S.W.1
AGENTS AT MANCHESTER, GLASGOW & NEWCASTLE-ON-TYNE.
**BEDFORD**

# WEEKLY PRICE CURRENT.

## COPPER.

| | £ | s. | d. |
|---|---|---|---|
| Standard cash | 35 | 0 | 0 |
| Three months | 35 | 12 | 6 |
| Electrolytic | 38 | 10 | 0 |
| Tough | 37 | 5 | 0 |
| Best selected | 37 | 15 | 0 |
| Sheets | 70 | 0 | 0 |
| India | 51 | 10 | 0 |
| Wire bars | 42 | 17 | 6 |
| Do., August | 42 | 17 | 6 |
| Do., September | 42 | 17 | 6 |
| Ingot bars | 42 | 17 | 6 |
| H.C. wire rods | 42 | 15 | 0 |
| Off. av. cash, June | 35 | 17 | 6 1/32 |
| Do., 3 mths., June | 36 | 10 | 10 1/32 |
| Do., Sttlmnt., June | 35 | 17 | 4 7/11 |
| Do., Electro, June | 39 | 7 | 10 1/11 |
| Do., B.S., June | 37 | 10 | 10 |
| Do., wire bars, June | 39 | 16 | 4 1/11 |
| Solid drawn tubes | | | 10½d. |
| Brazed tubes | | | 10½d. |
| Wire | | | 7d. |

## BRASS.

| | |
|---|---|
| Solid drawn tubes | 9½d. |
| Brazed tubes | 11½d. |
| Rods, drawn | 8½d. |
| Rods, extd. or rlld. | 5d. |
| Sheets to 10 w.g. | 7½d. |
| Wire | 7½d. |
| Rolled metal | 7½d. |
| Yellow metal rods | 5d. |
| Do. 4 × 4 Squares | 5½d. |
| Do. 4 × 3 Sheets | 5½d. |

## TIN

| | £ | s. | d. |
|---|---|---|---|
| Standard cash | 113 | 5 | 0 |
| Three months | 115 | 0 | 0 |
| English | 115 | 0 | 0 |
| Bars | 116 | 15 | 0 |
| Straits | 115 | 7 | 6 |
| Australian | 114 | 12 | 6 |
| Eastern | 117 | 15 | 0 |
| Banca | 118 | 2 | 6 |
| Off. av. cash, June | 105 | 0 | 8 3/11 |
| Do., 3 mths., June | 106 | 13 | 5 1/32 |
| Do., Sttlmt., June | 105 | 1 | 1 7/11 |

## SPELTER.

| | £ | s. | d. |
|---|---|---|---|
| Ordinary | 12 | 2 | 6 |
| Remelted | 11 | 5 | 0 |
| Hard | 9 | 5 | 0 |
| Electro 99.9 | 15 | 0 | 0 |
| English | 13 | 5 | 0 |
| India | 11 | 5 | 0 |
| Zinc dust | 20 | 0 | 0 |
| Zinc ashes | 3 | 0 | 0 |
| Off. aver., June | 11 | 10 | 2 17/32 |
| Aver. spot, June | 11 | 5 | 4 15/32 |

## LEAD.

| | £ | s. | d. |
|---|---|---|---|
| Soft foreign ppt. | 12 | 16 | 3 |
| English | 14 | 5 | 0 |
| Off. average, June | 11 | 15 | 4 3/11 |
| Average spot, June | 11 | 11 | 7 17/32 |

## ZINC SHEETS, &c.

| | £ | s. | d. |
|---|---|---|---|
| Zinc sheets, English | 20 | 0 | 0 |
| Do., V.M. ex-whf. | 19 | 5 | 0 |
| Rods | 22 | 0 | 0 |
| Boiler plates | 14 | 10 | 0 |
| Battery plates | 16 | 10 | 0 |

## ANTIMONY.

| | £ | s. | d. |
|---|---|---|---|
| Special brand, Eng. | 34 | 0 | 0 |
| Chinese | 23 | 2 | 6 |
| Crude | 21 | 0 | 0 |

## QUICKSILVER.

| | £ | s. | d. |
|---|---|---|---|
| Quicksilver | 16 | 15 | 0 |

## FERRO-ALLOYS AND STEEL-MAKING METALS.

| | |
|---|---|
| Ferro-silicon— | |
| 25% | £7 7 6 |
| 45/50% | £10 7 6 |
| 75% | £15 2 6 |
| Ferro-vanadium— | |
| 35/50% | 12/8 lb. Va. |
| Ferro-molybdenum— | |
| 70/75% c. free | 4/2 lb. Mo. |
| Ferro-titanium— | |
| 23/25% carbon-free | 9½d. lb. |
| Ferro-phosphorus, 20/25% | £15 10 0 |
| Ferro-tungsten— | |
| 80/85% | 1/8½ lb. |
| Tungsten metal powder— | |
| 98/99% | 1/11½ lb. |
| Ferro-chrome— | |
| 2/4% car. | £28 0 0 |
| 4/6% car. | £21 5 0 |
| 6/8% car. | £20 12 6 |
| 8/10% car. | £19 17 6 |
| Ferro-chrome— | |
| Max. 2% car. | £29 17 6 |
| Max. 1% car. | £33 15 0 |
| Max. 0.70% car. | £35 12 6 |
| 70% carbon-free | 9½d. lb. |
| Nickel—99% | £170 0 0 to £175 0 0 |
| Ferro-cobalt | 9/- lb. |
| Aluminium 98/99% | £85 0 0 |
| Metallic chromium— | |
| 96/98% | 2/7 lb. |
| Ferro-manganese (net)— | |
| 76/80% loose | £10 15 0 to £11 5 0 |
| 76/80% packed | £11 15 0 to £12 5 0 |
| 76/80% export | (nom.) £ 9 0 0 |
| Metallic manganese— | |
| 94/96% carbonless | 1/3 lb. |

Per ton unless otherwise stated.

## HIGH-SPEED TOOL STEEL.

| | |
|---|---|
| Finished bars, 14% tungsten | £0 2 0 |
| Finished bars, 18% tungsten | £0 2 9 |

Per lb. net, d/d buyers' works.

| Extras— | |
|---|---|
| Rounds and squares, 3 in. and over | 4d. lb. |
| Rounds and squares, under ½ in. to ¼ in. | 3d. lb. |
| Do., under ¼ in. to 5/32 in. | 1/- lb. |
| Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in. | 3d. lb. |
| Do., under ½ in. × ¼ in. | 1/- lb. |
| Bevels of approved sizes and sections | 6d. lb. |

Bars cut to length, 10% extra.

## SCRAP.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| South Wales | | | | | | | |
| Heavy steel | | | | | 2 | 0 | 0 |
| Bundled steel and shrngs. | 1 | 14 | 0 | to | 1 | 19 | 0 |
| Mixed iron and steel | | | | | 1 | 16 | 0 |
| Heavy cast iron | 2 | 2 | 6 | to | 2 | 5 | 0 |
| Good machinery for foundries | | | | | 2 | 7 | 6 |
| Cleveland— | | | | | | | |
| Heavy steel | | | | | 1 | 17 | 6 |
| Steel turnings | | | | | 1 | 5 | 0 |
| Cast-iron borings | | | | | 1 | 2 | 0 |
| Heavy forge | | | | | 2 | 13 | 0 |
| W.I. piling scrap | | | | | 2 | 10 | 0 |
| Cast-iron scrap | 2 | 2 | 6 | to | 2 | 4 | 0 |
| Midlands— | | | | | | | |
| Light cast-iron scrap | | | | | 1 | 17 | 6 |
| Heavy wrought | | | | | 2 | 7 | 6 |
| Steel turnings | | | | | | — | |
| Scotland— | | | | | | | |
| Heavy steel | | | | | 1 | 17 | 6 |
| Ordinary cast iron | | | | | 2 | 0 | 0 |
| Engineers' turnings | | | | | 1 | 5 | 0 |
| Cast-iron borings | | | | | 1 | 10 | 0 |
| Wrought-iron piling | | | | | 2 | 7 | 6 |
| Heavy machinery | | | | | 2 | 8 | 6 |

London—Merchants' buying prices delivered yard.

| | £ | s. | d. |
|---|---|---|---|
| Copper (clean) | 30 | 0 | 0 |
| Brass | 21 | 0 | 0 |
| Lead (less usual draft) | 10 | 10 | 0 |
| Tea lead | 7 | 10 | 0 |
| Zinc | 6 | 0 | 0 |
| New aluminium cuttings | 52 | 0 | 0 |
| Braziery copper | 27 | 0 | 0 |
| Gunmetal | 26 | 0 | 0 |
| Hollow pewter | 75 | 0 | 0 |
| Shaped black pewter | 56 | 0 | 0 |

## PIG-IRON.

*(f.o.t. unless otherwise stated.)*

| | |
|---|---|
| N.E. Coast— | |
| Foundry No. 1 | 61/- |
| Foundry No. 3 | 58/6 |
| Foundry No. 4 | 57/6 |
| Forge No. 4 | 57/- |
| Hematite No. 1 | 63/- |
| Hematite M/Nos. | 62/6 |
| N.W. Coast— | |
| Hem. M/Nos. d/d Glas. | 73/6 |
| „ d/d Birm. | 84/6 |
| Malleable iron d/d Birm. | 115/- |
| Midlands— | |
| Staffs common* | — |
| „ No. 4 forge* | 61/- |
| „ No. 3 fdry.* | 66/- |
| Shrops basic | — |
| „ Cold blast, ord. | — |
| „ „ roll iron | — |
| Northants forge* | 57/6 |
| „ fdry. No. 3* | 62/6 |
| „ fdry. No. 1* | 65/6 |
| Derbyshire forge* | 61/- |
| „ fdry. No. 3* | 66/- |
| „ fdry. No. 1* | 69/- |
| „ basic* | — |

*d/d Black Country dist.

| | |
|---|---|
| Scotland— | |
| Foundry No. 1 | 73/6 |
| „ No. 3 | 71/- |
| Hem. M/Nos. d/d | 70/- |
| Sheffield (d/d district)— | |
| Derby forge | 58/6 |
| „ fdry. No. 3 | 63/6 |
| Lincs forge | — |
| „ fdry. No. 3 | 63/6 |
| E.C. hematite | 78/- |
| W.C. hematite | 82/6 |
| Lancashire (d/d eq. Man.)— | |
| Derby forge | 62/- |
| „ fdry. No. 3 | 67/- |
| Staffs fdry. No. 3 | 67/- |
| Northants fdry. No. 3 | 65/6 |
| Cleveland fdry. No. 3 | 67/- |
| Dalzell, No. 3 (special) | 102/6 to 105/- |
| Glengarnock, No. 3 | 87/6 |
| Clyde, No. 3 | 87/6 |
| Monkland, No. 3 | 87/6 |
| Summerlee, No. 3 | 87/6 |
| Eglinton, No. 3 | 87/6 |
| Gartsherrie, No. 3 | 87/6 |
| Shotts, No. 3 | 87/6 |

## FINISHED IRON AND STEEL.

*Usual District deliveries for iron; delivered consumers' station for steel.*

| Iron— | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Bars (cr.) | 9 | 15 | 0 | to | 10 | 0 | 0 |
| Nut and bolt iron | 8 | 10 | 0 | to | 8 | 12 | 6 |
| Hoops | 10 | 10 | 0 | to | 12 | 0 | 0 |
| Marked bars (Staffs) f.o.t. | | | | | 12 | 0 | 0 |
| Gas strip | 10 | 10 | 0 | to | 12 | 0 | 0 |
| Bolts and nuts, ¾ in. × 4 in. | | | | | 12 | 5 | 0 |
| Steel— | | | | | | | |
| Plates, ship, etc. | 8 | 15 | 0 | to | 8 | 17 | 6 |
| Boiler plts. | 8 | 17 | 6 | to | 9 | 12 | 6 |
| Chequer plts. | | | | | 10 | 7 | 6 |
| Angles | | | | | 8 | 7 | 6 |
| Tees | | | | | 9 | 7 | 6 |
| Joists | | | | | 8 | 15 | 0 |
| Rounds and squares, 3 in. to 5½ in. | | | | | 9 | 7 | 6 |
| Rounds under 3 in. to ⅜ in. (Untested) | | | | | 6 | 12 | 6 & up. |
| Flats—8 in. wide and over | | | | | 8 | 12 | 6 |
| „ under 8 in. and over 5 in. | | | | | 8 | 17 | 6 |
| Rails, heavy | 8 | 5 | 0 | to | 8 | 10 | 0 |
| Fishplates | | | | | 12 | 0 | 0 |
| Hoops (Staffs) | | | | | 9 | 5 | 0 |
| Black sheets, 24g. | 8 | 5 | 0 | to | 9 | 5 | 0 |
| Galv.cor.shts.24g. | 9 | 15 | 0 | to | 10 | 0 | 0 |
| Galv. flat sheets | 10 | 5 | 0 | to | 10 | 10 | 0 |
| Galv. fencing wire, 8g. plain | | | | | 12 | 0 | 0 |
| Billets, soft | | | | | 5 | 0 | 0 |
| Billets, hard | | | | | 6 | 12 | 6 |
| Sheet bars | 4 | 12 | 6 | to | 4 | 17 | 6 |
| Tin bars | | | | | 4 | 12 | 6 |

## PHOSPHOR BRONZE.

Per lb. basis.

| | |
|---|---|
| Strip | 10½d. |
| Sheet to 10 w.g. | 12d. |
| Wire | 12½d. |
| Rods | 11½d. |
| Tubes | 1/4½d. |
| Castings | 11½d. |

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

## NICKEL SILVER, &c.

| | Per lb. |
|---|---|
| Ingots for raising | 7d. to 1/1 |
| Rolled— | |
| To 9 in. wide | 1/1 to 1/7 |
| To 12 in. wide | 1/1¼ to 1/7½ |
| To 15 in. wide | 1/1½ to 1/7½ |
| To 18 in. wide | 1/2 to 1/8 |
| To 21 in. wide | 1/2½ to 1/8½ |
| To 25 in. wide | 1/3 to 1/9 |
| Ingots for spoons and forks | 7d. to 1/3½ |
| Ingots rolled to spoon size | 10d. to 1/6½ |
| Wire round— | |
| 3/- to 10 g. | 1/4½ to 1/11½ |

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

## AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

| | Dols. |
|---|---|
| No. 2 foundry, Phila. | 17.26 |
| No. 2 foundry, Valley | 17.00 |
| No. 2 foundry, Birm. | 12.00 |
| Basic | 17.26 |
| Bessemer | 18.76 |
| Malleable | 18.76 |
| Grey forge | 18.26 |
| Ferro-mang. 80% | 85.00 |
| O.-h. rails, h'y, at mill | 43.00 |
| Billets | 29.00 |
| Sheet bars | 29.00 |
| Wire rods | 35.00 |
| | Cents. |
| Iron bars, Phila. | 2.09 |
| Steel bars | 1.65 |
| Tank plates | 1.65 |
| Beams, etc. | 1.65 |
| Skelp, grooved steel | 1.65 |
| Skelp, sheared steel | 1.65 |
| Steel hoops | 1.85 |
| Sheets, black, No. 24 | 2.15 |
| Sheets, galv., No. 24 | 2.70 |
| Sheets, blue an'l'd, No. 13 | 2.00 |
| Wire nails | 1.80 |
| Plain wire | 2.20 |
| Barbed wire, galv. | 2.55 |
| Tinplates, 100-lb. box | $5.00 |

## COKE (at ovens).

| | |
|---|---|
| Welsh foundry | 20/- to 21/- |
| „ furnace | 15/- to 16/- |
| Durham and Northumberland— | |
| „ foundry | 13/- |
| „ furnace | 13/- |
| Midlands, foundry | — |
| „ furnace | — |

## TINPLATES.

f.o.b. Bristol Channel ports.

| | | | |
|---|---|---|---|
| I.C. cokes | 20×14 box | | 13/9 |
| „ | 28×20 | „ | 27/6 |
| „ | 20×10 | „ | 20/- |
| „ | 18¾×14 | „ | 14/6 |
| C.W. | 20×14 | „ | 13/- |
| „ | 28×20 | „ | 27/- |
| „ | 20×10 | „ | 19/7½ |
| „ | 18¾×14 | „ | 14/6 |
| Terneplates | 28×20 | | 27/6 per box basis f.o.b. |

## SWEDISH CHARCOAL IRON & STEEL.

| | |
|---|---|
| Pig-iron | £6 0 0 to £7 10 0 |
| Bars, hammered, basis | £17 10 0 to £18 10 0 |
| Bars and nail-rods, rolled, basis | £15 17 6 to £16 15 0 |
| Blooms | £10 0 0 to £12 0 0 |
| Keg steel | £32 0 0 to £33 0 0 |
| Faggot steel | £20 0 0 to £24 0 0 |
| Bars and rods dead soft, st'l | £11 0 0 to £14 0 0 |

All per English ton, f.o.b. Gothenburg.

### TUBES AND FITTINGS.

Current Discounts.

| | *Tubes.* | *Fittings.* |
|---|---|---|
| Gas .. .. | 62½% | 57½% |
| Water .. | 58½% | 52½% |
| Steam .. | 55% | 47½% |

W.I. 12½% extra.

### DAILY FLUCTUATIONS.

**Standard Copper** (cash).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 37 | 17 | 6 | inc. | 37/6 |
| ,, | 3 .. | 36 | 18 | 9 | dec. | 18/9 |
| ,, | 6 .. | 37 | 1 | 3 | inc. | 2/6 |
| ,, | 7 .. | 36 | 10 | 0 | dec. | 11/3 |
| ,, | 8 .. | 35 | 0 | 0 | ,, | 30/- |

**Electrolytic Copper.**

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 41 | 0 | 0 | inc. | 10/- |
| ,, | 3 .. | 39 | 15 | 0 | dec. | 25/- |
| ,, | 6 .. | 39 | 15 | 0 | No change | |
| ,, | 7 .. | 39 | 15 | 0 | ,, ,, | |
| ,, | 8 .. | 38 | 10 | 0 | dec. | 25/- |

**Standard Tin** (cash).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 117 | 0 | 0 | inc. | 77/6 |
| ,, | 3 .. | 117 | 2 | 6 | ,, | 2/6 |
| ,, | 6 .. | 119 | 0 | 0 | ,, | 37/6 |
| ,, | 7 .. | 117 | 12 | 6 | dec. | 27/6 |
| ,, | 8 .. | 113 | 5 | 0 | ,, | 87/6 |

**Tin** (English ingots).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 118 | 0 | 0 | inc. | 50/- |
| ,, | 3 .. | 118 | 5 | 0 | ,, | 5/- |
| ,, | 6 .. | 120 | 0 | 0 | ,, | 35/- |
| ,, | 7 .. | 118 | 15 | 0 | dec. | 25/- |
| ,, | 8 .. | 115 | 0 | 0 | ,, | 75/- |

**Zinc Sheets** (English).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 20 | 0 | 0 | No | change |
| ,, | 3 .. | 20 | 0 | 0 | ,, | ,, |
| ,, | 6 .. | 20 | 0 | 0 | ,, | ,, |
| ,, | 7 .. | 20 | 0 | 0 | ,, | ,, |
| ,, | 8 .. | 20 | 0 | 0 | ,, | ,, |

**Spelter** (ordinary).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 12 | 18 | 9 | inc. | 7/6 |
| ,, | 3 .. | 13 | 3 | 9 | ,, | 5/- |
| ,, | 6 .. | 12 | 16 | 3 | dec. | 7/6 |
| ,, | 7 .. | 12 | 16 | 3 | No change | |
| ,, | 8 .. | 12 | 2 | 6 | dec. | 13/9 |

**Lead** (English).

| | | £ | s. | d. | | |
|---|---|---|---|---|---|---|
| July | 2 .. | 14 | 15 | 0 | inc. | 5/- |
| ,, | 3 .. | 14 | 15 | 0 | No change | |
| ,, | 6 .. | 14 | 15 | 0 | ,, | ,, |
| ,, | 7 .. | 14 | 15 | 0 | ,, | ,, |
| ,, | 8 .. | 14 | 5 | 0 | dec. | 10/- |

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| Year. | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Yearly average. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. | £ s. d. |
| 1896 .. .. | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 2 6 | 6 5 0 | 6 10 0 | 6 3 0 |
| 1897 .. .. | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 8 |
| 1898 .. .. | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 10 0 | 6 15 0 | 6 15 0 | 7 0 0 | 6 11 6 |
| 1899 .. .. | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 12 6 | 10 12 6 | 8 12 6 | 8 12 6 | 8 12 6 | 9 2 6 | 9 7 6 | 9 17 6 | 8 2 9 |
| 1900 .. .. | 9 17 6 | 10 7 6 | 10 7 6 | 10 7 0 | 10 12 6 | 7 12 6 | 10 12 6 | 10 12 6 | 10 12 6 | 9 17 6 | 9 2 6 | 9 2 6 | 10 3 8 |
| 1901 .. .. | 9 2 6 | 8 2 6 | 8 2 6 | 7 12 6 | 7 12 6 | 7 12 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 11 2 |
| 1902 .. .. | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 |
| 1903 .. .. | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 |
| 1904 .. .. | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 | 7 2 6 |
| 1905 .. .. | 6 17 6 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 2 6 | 7 2 6 | 7 2 6 | 7 7 6 | 7 0 0 | 7 7 6 | 7 2 0½ |
| 1906 .. .. | 7 10 0 | 7 17 6 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 7 15 0 | 8 7 6 | 7 15 1½ |
| 1907 .. .. | 8 7 6 | 8 7 6 | 8 7 6 | 8 7 0 | 8 7 6 | 8 7 6 | 8 10 0 | 8 10 0 | 8 10 0 | 8 5 0 | 8 5 0 | 8 0 0 | 8 7 1 |
| 1908 .. .. | 8 0 0 | 7 10 0 | 7 10 0 | 7 10 6 | 7 10 0 | 7 10 0 | 7 10 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 6 8 |
| 1909 .. .. | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 | 7 0 0 |
| 1910 .. .. | 7 1 10½ | 7 6 3 | 7 7 6 | 7 7 0 | 7 7 6 | 7 7 6 | 7 7 6 | 7 7 6 | 7 7 6 | 7 6 3 | 7 5 0 | 7 5 0 | 7 6 5 |
| 1911 .. .. | 7 5 0 | 7 5 0 | 7 5 0 | 7 5 6 | 7 5 0 | 7 5 0 | 7 5 0 | 7 5 0 | 7 5 0 | 7 8 9 | 7 10 0 | 7 10 0 | 7 6 2½ |
| 1912 .. .. | 7 12 6 | 7 12 6 | 7 12 6 | 7 15 0 | 7 15 0 | 8 2 6 | 8 2 6 | 8 2 6 | 8 12 6 | 8 12 6 | 8 12 6 | 8 15 0 | 8 2 3½ |
| 1913 .. .. | 8 17 6 | 8 17 6 | 8 17 6 | 8 17 0 | 8 17 6 | 8 17 6 | 8 17 6 | 8 7 6 | 8 7 6 | 8 7 6 | 8 7 6 | 7 17 6 | 8 12 6 |
| 1914 .. .. | 7 17 6 | 7 17 6 | 7 17 6 | 7 13 9 | 7 12 6 | 7 12 6 | 7 12 6 | 9 2 6 | 9 2 6 | 9 2 6 | 9 2 6 | 9 2 6 | 8 6 4½ |
| 1915 .. .. | 9 3 6 | 9 18 1 | 10 7 6 | 10 16 6 | 10 17 6 | 13 2 6 | 13 2 6 | 13 2 6 | 13 7 6 | 14 2 6 | 15 2 6 | 15 18 6 | 12 10 1 |
| 1916 .. .. | 17 2 6 | 17 2 6 | 17 2 6 | 17 6 3 | 17 7 6 | 17 7 6 | 17 7 6 | 17 7 6 | 17 7 6 | 17 7 6 | 17 7 6 | 17 7 6 | 17 6 1 |
| 1917 .. .. | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 |
| 1918 .. .. | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 |
| 1919 .. .. | 17 2 6 | 17 2 6 | 17 2 6 | 17 2 6 | 24 6 3 | 24 6 3 | 24 6 3 | 25 9 0 | 26 7 6 | 26 7 6 | 26 7 6 | 26 17 4 | 22 14 9 |
| 1920 .. .. | 28 0 0 | 28 12 6 | 33 15 0 | 35 5 0 | 35 15 10 | 38 17 6 | 38 17 6 | 38 17 6 | 38 17 6 | 38 17 6 | 36 17 6 | 36 17 6 | 35 14 9 |
| 1921 .. .. | 29 1 3 | 23 5 0 | 21 12 6 | 20 0 0 | 20 0 0 | 20 0 0 | 17 5 0 | 15 0 0 | 14 4 0 | 13 15 0 | 13 10 0 | 12 18 0 | 17 5 10 |
| 1922 .. .. | 16 5 0 | 15 13 9 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 14 0 0 | 13 4 6½ |
| 1923 .. .. | 14 0 0 | 15 0 0 | 15 0 0 | 15 0 0 | 15 6 0 | 15 0 0 | 15 0 0 | 15 0 0 | 15 0 0 | 15 0 0 | 14 16 0 | 14 15 0 | 14 18 3½ |
| 1924 .. .. | 14 15 0 | 14 15 0 | 14 15 0 | 14 15 0 | 14 15 0 | 14 13 9 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 12 4½ |
| 1925 .. .. | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 |
| 1926 .. .. | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 |
| 1927 .. .. | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 14 10 0 | 12 10 0 | 12 10 0 | 14 3 4 |
| 1928 .. .. | 12 10 0 | 12 7 6 | 12 0 0 | 11 13 6 | 11 15 0 | 11 12 6 | 11 10 0 | 11 10 0 | 11 10 0 | 11 10 0 | 11 10 0 | 11 10 0 | 11 14 10½ |
| 1929 .. .. | 11 10 0 | 11 10 0 | 11 10 0 | 11 10 0 | 11 9 0 | 11 5 0 | 11 5 0 | 11 5 0 | 11 5 0 | 11 2 0 | 11 0 0 | 11 0 0 | 11 5 11 |
| 1930 .. .. | 11 0 0 | 11 0 0 | 11 0 0 | 10 16 3 | 10 15 0 | 10 15 0 | 10 15 0 | 10 15 0 | 10 15 0 | 10 15 0 | 10 15 0 | 10 15 0 | 10 16 4½ |
| 1931 .. .. | 10 15 0 | 10 15 0 | 10 15 0 | 10 10 0 | 10 10 0 | 10 10 0 | — | — | — | — | — | — | — |


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